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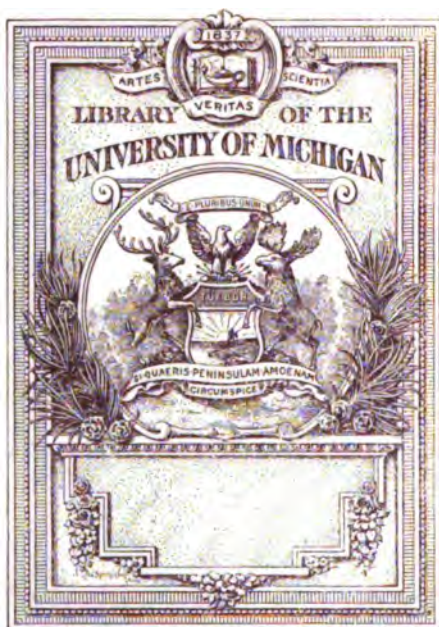
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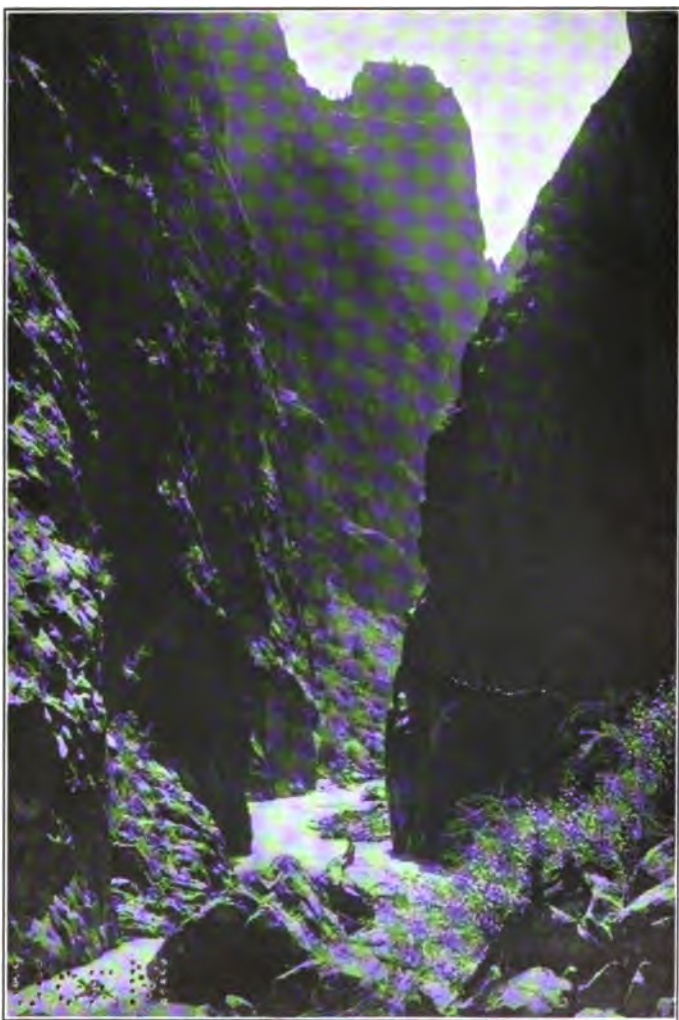
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THE CONSERVATION OF WATER

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THE GUNNISON CAÑON CLOSE TO THE DAM SITE

The dam which has been erected here returns the Gunnison water through a tunnel in the side of the gorge to the Uncompaghre Valley, ten miles away, where it provides homes upon fertile farms for thousands of families. (*See page 211.*)

THE CONSERVATION OF WATER

BY

JOHN L. MATHEWS

AUTHOR OF "RE-MAKING THE MISSISSIPPI," ETC.

Illustrated from Photographs



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CONTENTS

CHAPTER	PAGE
I WATER AS A RESOURCE	1
II FLOODS AND FLOOD PREVENTION . .	28
III STORAGE	53
IV MUNICIPAL SUPPLY AND THE PURIFI- CATION OF RIVERS.	79
V WATERPOWER, THE MINING OF THE WHITE COAL.	97
VI WATERPOWER IN NATIONAL DEVELOP- MENT	119
VII SWAMP DRAINAGE	144
VIII IRRIGATION	176
IX CONSERVATION OF THE SOIL	220
X NAVIGATION	245
XI THE RESULTS OF THE CONSERVATION OF WATER	267
INDEX	283

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ILLUSTRATIONS

The Gunnison Canon close to the dam site	<i>Frontispiece</i>
	FACING PAGE
Creating a Water Farm	8
An Embryo Water Farm	16
Too Closely Grazed Forest	32
A Levee against Floods	40
A Water Farm	58
A Mountain Reservoir	64
Cutting Timber in a National Forest	72
Chicago Sanitary Canal	84
Site of the Wachusett Reservoir, near Clinton, Massachusetts	88
The Wachusett Dam completed, with the reservoir full	92
'Lije Williams' Mill	100
Potomac Great Falls. Undeveloped Power	104
A Dam under Construction	110
The Bear Trap Dam in the Chicago Drainage Canal	116

ILLUSTRATIONS

	FACING PAGE
Mining White Coal	130
Swamp Drainage	146
Swamp Drainage	152
Harvest on a Drained Swamp	170
Irrigation Ditches in an Orchard	186
The Roosevelt Dam	196
Apaches working on an Irrigation Project	200
A Sagebrush Desert	208
Apple Orchards in the Yakima Desert	216
Disastrous Tree Cutting	222
Riparian Erosion	232
Hillside Erosion	242
A Well-ordered River	246
A Lock on the Illinois	252
A Revetment Mattress	258
Steamboats on the Upper Missouri	264
The Rhone, a well-ordered river	276

THE CONSERVATION OF WATER

THE CONSERVATION OF WATER

CHAPTER I

WATER AS A RESOURCE

Ezry Perkins sold his river-bottom farm the other day — that no-account, marshy, rocky tract that stretches along the upper Punxit creek in the very northwest part of New Hampshire. Ezry could hardly contain himself for mirth when he came down to the store to tell about it.

“Sold th’ ol’ bottom farm,” he gasped, when he had unwrapped himself from his muffler. “By gum, I be’n a-payin’ taxes on it sixty years an’ never raised a crop on it. But I got them taxes back now; city feller named Emerson give me five dollars an acre.”

“Look out, Ezry — you’ll be took up fur swindlin’,” said the postmaster.

THE CONSERVATION OF WATER

"You're one of them reg'lar green-goods, ain't ye, Ez?" asked the village humorist.

"Did he say what he'd cal'late to do with it?" asked the village magnate cautiously.

"Wal — I ast him," said Ezry, dubiously. " 'What ye goin' to raise on it?' I says.

" 'I 'm a-goin' to raise water on it,' says he, 'an' mine some white coal.'

" 'Wal,' I says, 'I never heard tell of no coal, black or white, bein' dug out of them granite rocks,' I says. 'But as fur 's water goes, you got a good start right now.'

" 'That 's why I 'm buyin',' says he. 'Little draps of water, little grains of sand,' — and he goes off to his team talkin' some nonsense rhyme about it. I guess he's one of them crazy rich fellers. Good Lord! Five dollars an acre fur that rocky bottom."

There was mirth in Ezry's village home that night and for a week afterwards over the ease with which the "city feller" had been separated from his money; but the wise stranger was over on the next creek buying another

WATER AS A RESOURCE

bottom farm, with a chance for a dam at its foot and a watershed above it, paying money without regret, and passing along his wise saying about white coal mines.

He was a little ahead of the times up there, "getting in on the ground floor" he would have called it, as a landholder, that when a movement which he foresaw got well under way his newly acquired farms would be salable at high prices for water storage.

The rest of us will catch up with him soon, and even Ezry will learn in time the meaning of those mysterious words "water farming" and "white coal." The storage of water and its use for power — combined they make a large part of the most important movement in which we are involved to-day. It is a movement the country at large does not yet understand, so suddenly has the progress of invention and the diminution of our coal supply brought it upon us. It is a movement which involves the world.

White Coal itself is not an American phrase,

THE CONSERVATION OF WATER

but comes to us from Switzerland and from France — to be exact, from the valley of the Durance and the city of Grenoble. It has long been the custom of French writers to refer to the fagots gathered by the peasants, and to any form of wood for burning — and even to the growing forests — as “green coal.” A young man in Grenoble seeking a phrase by which to catch the attention of those whom he wished to interest in the little understood development of large hydraulic powers borrowed and altered this.

“White Coal,” he declared from the platform, “will be the fuel of our children; the white coal which pours down the mountain-side in unending abundance.”

It was so that he described the white water which, released from the melting glaciers of the Alps of Savoy plunges down over precipices and through the beds of torrents to feed the Durance. The power of this falling water is to supplant the power of steam. And as
(for water farms, engineers are already learn-

WATER AS A RESOURCE

ing that many an acre of land which does not produce a dollar a year in crops — and many an acre which produces even ten to twenty dollars — can be used more profitably in water farming. Such an acre will earn fifty to one hundred dollars a year if it can be made part of the bed of a big reservoir high above sea level, and used to store water in high water seasons to provide power for mill wheels when the rains have ceased and the dry autumn has come.

During the next two or three decades water storage and the “mining” of white coal are destined to be among our greatest activities.

Over the whole United States there falls in a single year an average of thirty inches of water. That is, if the water lay where it fell, not running down hill, seeping into the soil, or evaporating, it would form an average cover over the whole region thirty inches deep — in some places more than eight feet deep, in others but five or six inches. This total rainfall amounts in a year to 200,000,000,000 000

THE CONSERVATION OF WATER

cubic feet. Having fallen upon the earth it escapes in various ways. One-fifth of it finds its way to the sea through running streams — enough to make six Mississippis. Some of it sinks into the earth, is absorbed by the roots of trees and plants, and escapes through their leaves into the air by the process called transpiration, or the breathing of plants. Some of it — and this is a very large quantity — is taken up into the trees and plants and goes to form the greater part of their cells and of their fruit. And a great part of it evaporates again into the air.

No other element in nature plays so profound a part in our existence as this deluge. The whole surface of the continent, mountains, meadows, plains and river courses, has been shaped by it in the long centuries during which it has sought the sea, eroding, carrying on and dropping sand, silt, and gravel and even huge boulders in its path, cutting gorges through mountains, filling up depressions, making habitable lands uninhabitable and turning sandy

WATER AS A RESOURCE

deserts into gardens. The climate of the earth and our ability to live upon it depend upon the moisture in the air which stores and regulates the heat of the sun's rays. Every living thing upon which we in turn live, depends upon this water; and in the end our ability to move about the earth, and the power to run our factories and trains, will all come from water. There is no other resource with which nature has endowed us which is so important for mankind, or which has been so long neglected and so little studied by man.

This enormous amount of water which now runs to waste, this sixfold Mississippi pouring its idle and unutilized flood into the sea and carrying with it every year a billion tons of our richest soil — is mainly a source of destruction and loss to the nation. Yet penned up and harnessed, treated not as an element of danger but as a resource, the wild water and flood water penned in reservoirs and the river beds developed for their best use, it would produce an addition to the national wealth so

THE CONSERVATION OF WATER

great as to be almost inconceivable.) It means a green and bountiful earth storing up treasures of fertility instead of having them, as now, swept out to sea; swamps drained, deserts irrigated, forests restored, swift water harnessed, and channels opened to navigation over the entire country. These are the material things which Conservation is to attain;—but in studying it we shall find that it will bring us also closer fellowship, among states and individuals; and public control of the running water and public prosperity from it rather than private development and the enrichment of only a few.

Wild water, the unrestrained run-off of the surplus rainfall, is one of the most destructive forces in nature. It cuts away the earth, dissolves and washes out the nutritive elements in the soil, wears chasms in the hillsides, fills up the river channels with débris, and dumps into the ocean every year more of our accumulated elements of fertility than are consumed in several years' crops.



CREATING A WATER FARM

CREATING A WATER FARM

The concrete dam, which is being erected across the valley, will hold back the water of the river and create storage over all the land in the foreground. Originally of little value, this land will have a new earning power from the water which is stored over it.

A water farm can often be thus created at headquarters by the construction of a small dam across a narrow valley, which, by holding back a large volume of water, makes the submerged land worth more (in its benefit to power users, to navigators, and to persons whose farms were formerly overflowed by floods) than they could possibly be made in ordinary agriculture.

WATER 'AS A RESOURCE

The example of the Mississippi alone should be a lesson never absent from the minds of Americans until we have corrected our rivers. For if there were one hundred thousand men standing on its banks, with shovels and an unlimited supply of rich earth at hand, and if they toiled twelve hours every day, three hundred and sixty-five days in the year, they could not throw into the Mississippi as much soil as it carries annually out into the Gulf of Mexico.

The heavy rains come in the springtime and sweep down the swift valleys doing tremendous damage. In the Mississippi they cause the river to rise through a thousand miles of its way more than fifty feet above standard low water — and this in a river of so great width that it then discharges more than two million cubic feet of water each second. Before levees were built this flood overwhelmed thirty-four thousand squares miles of land below Cairo every year, and made a river forty miles in width. Yet in a few months this drops away until there is only a ragged river, with broken

THE CONSERVATION OF WATER

and disfigured banks; which would have, but for our engineers, but two feet of water over its shoalest bars, and these bars formed of sand which was dropped by the greedy stream as it swept the more fertile and lighter silt away.

We have spent sixty million dollars to build levees to protect land from overflow below Cairo — and we have it returned to us now every year by the crops grown on the protected land. But leveeing was only a makeshift. The great work is still to do, the floods themselves to be stopped and the erosion with them, by the creation of reservoirs at headwaters; reservoirs with massive dams for the big rivers, and smaller reservoirs ultimately even on the little creeks which are destined to serve our farms and furnish power to haul the farmers' plows.

It is almost impossible to estimate the value of the power of this water running to waste, which we shall describe in a later chapter. It is an extremely conservative estimate to say that there is in our rivers and brooks power

WATER AS A RESOURCE

capable of development equal to 50,000,000 horsepower. It may in the end be double this. To produce a horsepower by burning coal under a boiler requires not less than thirteen tons a year, even when economy of the best type is practiced. This waterpower, therefore, represents the equivalent of 650,000,000 tons of coal burned every year — and all going to waste. And as we actually mine five hundred million tons of coal a year, and waste an equal amount in getting it out, this waterpower unharnessed and undeveloped represents a needless reduction in our total coal supply of one billion tons a year. That is, it is equal to doing everything we are doing now with coal, and doing most of it considerably better.

In the western states stored water, held through the dry season, becomes valuable for irrigation — for watering in the dry months the lands which otherwise would not produce crops, but which with water applied produce bountifully. Irrigation is yet in its infancy. It has been said and probably truthfully that

THE CONSERVATION OF WATER

there is water enough in the arid regions, and in position to be used profitably, to water 75,000,000 acres of land. This land produces sometimes \$100 an acre, sometimes only \$50, but often \$1,000 or even \$3,000 an acre in crops. To call \$300 an acre-year for irrigated crops an average is to take a low figure. Yet even at this figure this irrigated land, the use of which depends entirely upon the proper Conservation of Water, will add to our crop value \$22,500,000,000, — or several times the present crop value of the nation.

The drainage of swamps is another feature of Conservation, and there are of these also 75,000,000 acres capable of being drained and added to our agricultural lands. This results in a treble benefit — the reduction of swamp fevers, the turning of stagnant water into useful channels, and the addition of arable soil. There is practically none of this land which will not produce in a year \$100 an acre, and the whole will some day add \$10,000,000,000 to our possible crops.

WATER AS A RESOURCE

Navigation, the carrying of freight by water, is just in its infancy, and depends upon the storage and Conservation of Water to make the channels safe and useful. In twenty years the rivers in the heart of the country which are now idle ought to carry as much tonnage as the Great Lakes carry to-day, more than 50,000,000 tons a year, and the saving on this over rail haul will average more than one dollar for each ton.

Waterpower, irrigation, swamp drainage, navigation — and soil preservation — these, with forestry, are the great profit makers for the nation in the Conservation of Water. But there are other elements which enter in and which are as necessary to the public health and to continued prosperity. The purification and storage of water for municipal purposes is one of these — and offers problems daily growing more pressing and more difficult to solve. The provision of an enormous food supply in protected waters by the propagation of fish is a factor too little considered, but from which the

THE CONSERVATION OF WATER

state of Illinois alone is now producing an income of \$1,000,000, a year. Flood protection, incidental to the other provisions will save us from \$75,000,000 to \$100,000,000 a year, and unmeasurable inconvenience and unhappiness.

✓ With all these values pertaining to water the question of the ownership of it becomes of vital importance; and in fact the settlement of nearly every question which is brought up under this subject of Conservation depends in some degree upon water title. Water titles are to-day as important as land titles, and in some cases even more so. There are many instances already in America of districts in which individuals have secured title under color of law to the entire water in a big river; and no person owning land on the stream is allowed to use that water without the owner's permission and without paying him a tax for it.

In the old days when water was of no importance except for running small mill wheels, this question seldom arose. Under the English law, which makes every concession for the establish-

WATER AS A RESOURCE

ment of private as against public right to land or water, there grew up a common law which was imported into our eastern colonies and which is the basis of our doctrine of riparian rights. By this common law, enacted in many states into statute, the owner of any piece of land had the right to use the water while it flowed past his land.

“ Water flows and should flow as it is accustomed to flow ” says this old law. Under it a man may erect a dam and use the power of the water passing his land. He may hold it up temporarily and operate a fish pond with it. He may divert it into his house or factory for use and discharge it again into the stream. But he cannot draw it from the river bed for irrigation so as sensibly to diminish the supply of the next man lower down. He may not befoul it so as to injure any man lower down; and he may not impound it for mill purposes in any way to interfere with the steady operation of power or of navigation by the land of his neighbor below. To build a dam he must own

THE CONSERVATION OF WATER

the land, or buy the consent of the owner of land, on the opposite side of the river; but the need of grist mills was recognized in a statute which allowed the mill builder to dam up the water so that it overflowed the land of his neighbors upstream, thus creating a mill pond, for which he paid damages.

This law being brought to America underwent in our eastern states several remarkable changes. There was a division of opinion regarding the ownership of the bed of a stream. In some states the state kept the ownership of all land under water, in others the individuals were conceded to own the bottom from each side "*ad filium aquae*" — to the thread of the channel. That is, the owners on each side extended out under the river until their land met in mid-channel.

But with the decision of Chief Justice John Marshall in the case of *Gibbons against Ogden*, in the United States Supreme Court in 1824, this whole subject received a new turn. Justice Marshall established then the fact that all



AN EMBRYO WATER FARM

AN EMBRYO WATER FARM

Here is a typical reservoir site of the best sort, high in the mountains. It has already been set aside by the Reclamation Service for storage. The lake, surrounded by lofty mountains, will be increased many times in size by a dam across its foot. It will store an immense amount of water from melting snows and rain. The forest covering the mountains above it will hold up a great deal more and release it into the lake by slow seepage. Fire lanes and careful ranger service will maintain the forest against fire, and scientific cutting will make it a source of profit.

WATER AS A RESOURCE

navigable waters and all rivers flowing into them so far as they affected the carrying of commerce, were directly under the control and regulation of Congress. This wiped away at once the riparian and state control of such streams. Out of it grew the situation which in general prevails now east of the Mississippi and in some states west of it.

Congress controls all navigable rivers to the extent that no person can deflect water from them, construct works in them, build or maintain a dam in them, erect a bridge over them, dredge them, or in any way change them without Congressional content. There is a principal matter still in dispute, as to how far this authority extends. Every little tributary on headwaters may affect the storage of these rivers, and the establishment of forests over the headwaters may do the same. Opinion on the ability of Congress to extend its authority over the small streams, however, is widely varied. Personally I believe, and before this book is finished the reader perhaps will also,

THE CONSERVATION OF WATER

that every tributary of a navigable river to its remotest source should be under the general control of the same central authority.

In the eastern states the bed of each navigable river belongs as a general thing to the state — that is, below low water line. Some states have provided in their constitution that the bed of a river can never be alienated, and thus New Orleans is able to erect wharves along her waterfront on property which must always remain in the ownership of the people. Unnavigable rivers are under the state control only for the enforcement of the old common law. In many states a power company has but to secure the necessary land for the dam and mill pond and it obtains by that act the right to erect a dam and use the power, without regard to the rights of anyone else in the descent of that water. A hundred reservoirs might be erected above the dam, and under existing laws the dam owner would use the power — as they do now on the Mississippi — without making any return whatever to the owner of the storage.

WATER AS A RESOURCE

In the western states where life itself depended upon securing a supply of water, ownership to running water became a valuable asset even before irrigation was more than a beginning in Utah. Almost at once the doctrine was established and gradually enacted into laws in the several territories and states, that the first person to levy on a river and to put to beneficial use a given amount of its water should thereafter have the first right to the use each year of that same amount of water. No person higher up could take it from him. In the same way each subsequent user got his right, and they were entitled to divide the water in time of famine in order of precedence of title.

“Prior Right” instead of riparian right thus became the key of the western water situation and out of it has grown both the safety and the danger of the present situation. As applied to irrigation it meant simply that one Jones, having taken up a tract of land capable of being irrigated from the Snake river, posted on the river bank and recorded with the Secretary of

THE CONSERVATION OF WATER

State a notice that he had "filed upon" ten second feet, or twenty second feet of the flow of the river, to irrigate his land, and he claimed the right to that water. If there came a dry season when there was not enough water to satisfy those who had filed before him he must go without. He could, however, draw only as much water as he could put to beneficial use. "The right to the beneficial use of water shall never be denied" reads the law of some of the states.

So it happened on a certain river in Utah that farmer after farmer filing upon the water of the stream there came at last to be seven times as much water preëmpted as actually flowed in the stream at low water. This led to a meeting of the farmers and it was found most of them were wasting water. A time schedule was adopted by which each drew his water in certain specified hours, with the result that there proved to be abundant water for all concerned.

The development of large irrigation tracts

WATER AS A RESOURCE

and the taking of water in large volume for equitable distribution through canals makes for economy the same way; but it quickly comes to the point on a busy river where every person who would take an additional amount of water out of the river bed at low water must build a reservoir up at headwaters and store from the floods and release at low water as much as he intends to take out lower down. The federal government has had to do exactly this for the Tieton project in the Yakima valley.

In this way through the careful establishment of prior rights, the survey and measurement of a stream and the provision by the state of an outside amount per acre which no farmer can exceed, the title to water was fairly established, except as far as reservoiring was concerned — when there appeared the water-power complication. Waterpower has the same right to file and claim water as irrigation has — or as mining or milling has. It, too, is a “beneficial use.” John Smith, a water-power man, coming to a western river, and finding

THE CONSERVATION OF WATER

that it has an abundant flow over a fall in its lower course, filed notice that he claimed this power, and proceeded to develop it. He laid claim not to a specific volume, perhaps, but to "the entire flow and discharge" of the river.

Next summer a wandering pioneer discovered a fine tract of land higher up on the stream, settled upon it, and filed a notice of the beneficial appropriation of water for irrigation. Instantly the water-power owner was in court with him, and secured an injunction restraining him from diverting the water to which the mill wheel has a right. The injunction stands, and irrigation on that river is suspended unless the lack of water can be supplied by reservoirs.

This is not a fanciful case. It exists in many places to-day. Thus in Montana, on the Missouri river, the United Missouri River Power Company has at Great Falls a "Prior Right" to all the water naturally flowing in the Missouri river. Some distance above there is a big tract of land known as Prickly Pear val-

WATER AS A RESOURCE

ley, which the state desires to irrigate. This irrigation cannot be done, however, and the state is prevented from adding this fertile and productive area to its resources, by the fact that the water title of the Power Company is complete.

Exactly the same state of affairs prevails in Oregon in the valley of the Willamette, and in California there is at least one river so tightly owned by a single individual that no person can even dig a well in its vicinity and take water by seepage without paying a fee to him.

This state of affairs and the rapid development of power in our rivers has given rise to the need for a new set of laws on water titles which shall protect the public right first and the individual right second. Switzerland and France are marking the way in this direction. Switzerland has passed a law which is based upon the fact that water drains from the common land, and is and should remain common property. Any power that it attains by force

THE CONSERVATION OF WATER

of position depends not upon the land beside it but upon the land on which the water falls and the authority which establishes the laws permitting its free passage. Therefore the right to develop power in a stream is a public not a private right. No person may even harness a brook on his own farm without a permit from the state assembly, and if it is a big power in a river between two states the national assembly must give the permission. Either state or national assembly decides how much he shall pay for the privilege each year — an assessment per horsepower — and sets the price at which he can sell his output. The tax is paid to the individual states, but the right to control and direct the development is retained in the people.

France has gone even a step farther and now has a project of law under consideration by which, if it be adopted, in a few years all water-powers will revert to the nation. It is declared that all powers over two hundred and fifty horse are subjects of national concession and

WATER AS A RESOURCE

that all existing franchises expire in fifty years. Hereafter no franchise exceeding fifty years shall be granted. Every mill owner shall have his tax and his charges regulated by the state, so that he shall pay fair dividends on his actual money investment, and shall also accumulate a sinking fund so that when his franchise expires his plant will be paid for. The state shall then take it over and sell the franchise at auction with the right to use the plant, for another fifty years.

This movement is but slowly gaining headway but its effect is already apparent in many of our states which are making new laws, feeling their way toward proper water title definition. Oregon is the farthest advanced of all states at the present time.

“All water within the state from all sources of water supply belongs to the public.”

So reads the Oregon law. No person may file for irrigation without permission of the state water board. No person may file for power without the same permission. Water

THE CONSERVATION OF WATER

used for power must pay a tax of from 25 cents to \$2 per technical horsepower — about 50 cents to \$3.50 per commercial horsepower. The law does not go far enough yet, but it provides for limited franchises, for public ownership, and for the gradual straightening out and regulation of disputed titles. It is the beginning of an advance which will be well worth while.

No other state has taken so radical a step as Oregon, though Wisconsin has assumed supervision of her dam-sites and put them under control of her forest service; and has taxed her waterpowers to pay for storage at headwaters. The national Congress, which has control of dams in navigable waters, has long been in the habit of giving away the power in these dams without charge and without regulation. Sometimes the right to erect a dam was given, sometimes the dam was built by the government and the power was given cost free to the first person who asked for it. President Roosevelt put a stop to this wasteful procedure by vetoing the

WATER AS A RESOURCE

gift of Rainy river falls; and there has grown up a modified system of giving limited grants with a tax upon the power. The extent of Congressional authority has not yet been determined, nor has any definite plan been adopted. That, however, must come very soon, for the Conservation of Water is so vital a subject and the ownership of water is of such immense importance that we cannot long continue slipshod control of it.

There is hardly an item in our lives to which we can turn without finding some benefit accruing from Conservation and especially from the proper care of our water resource. In the following chapters we shall take up in turn the chief elements of this work and try to simplify and explain them.

CHAPTER II

FLOODS AND FLOOD PREVENTION

In the summer of 1909 the farmers on the bottom lands along the Mississippi harvested an unusually bountiful winter wheat crop. The season was early, the river had shown no sign of a great flood, and with much good heart they cut and shocked the grain — worth then at the farm one dollar a bushel. The work was hardly done however, and the wheat in shock ready for threshing still stood on the fields, when, almost without warning, a flood wave came down the Mississippi. The June rise, delayed but mighty, swept over the banks, gathered in the wheat shocks, and carried a winter's crop away to the sea. Distress and want followed in many homes. How great the loss was it is impossible to say. A single farmer at Prairie du Rocher lost his entire yield, worth

FLOODS AND FLOOD PREVENTION

\$2,000 as it stood. But this loss by the farmers is considered so insignificant compared to the millions lost in the cities by the same catastrophe that no one has taken the trouble to record it. In Missouri alone, that year, the June rise caused a loss of more than \$18,000,000.

Yet figures are nothing to estimate by, for the loss caused by wild water running unrestrained down an overflowed valley is much more in human suffering, in actual loss of life and destruction of happiness and contentment, than in the annihilation of profits and of property.

Nothing in the world is more destructive than a great flood — unless it should be a prolonged and widely extensive drought in crop season. The river filled with too much water swells until it overflows its banks, fills the streets of the cities, flows into the houses and factories, puts out furnace fires, destroys property, stops business, and causes losses which in a single week in a single city may run well up into the

THE CONSERVATION OF WATER

tens of millions of dollars. In the country they sweep over the fields, bear away the crops waiting to be housed, tear down and sweep away barns and frame dwellings, often overlay the rich farm with a deposit of sterilizing sand, and sometimes gouge out and carry away whole acres of rich land.

Lives are lost, business is stopped, transportation is brought to an end, and no man may estimate all the losses which a single river such as the Ohio can create in a single flood. When it recedes fragments of houses and the wreckage of farmsteads line its banks and are even seen caught in the branches of trees. Cities and houses are deep in mud which must be shoveled off and cleared away, and all this mud represents fertile soil stolen from the farmer's field and washed down upon the cities. In the mountain valleys and in the deforested regions bridges and railways are swept away, gravel is often piled six to ten feet deep in the village streets or over the tracks. A single flood in Utah in 1909 destroyed more than one

FLOODS AND FLOOD PREVENTION

hundred miles of a track, made it impossible for a great railway system to run its trains through a period of six months, and caused the expenditure of \$14,000,000 to rebuild the destroyed tracks before traffic could be resumed.

There is scarcely a river in America — none that I know of except the Des Chutes — which is not subject to the succeeding floods and low waters. Greatest of all are those upon the Mississippi and its tributaries, and we may consider them as illustrating the matter and offering us both the need and the manner of counteracting them.

The Mississippi is formed of three great rivers (and many smaller ones) which rise in regions separated by more than 2,000 miles of the heart of our country, and on which exist conditions of climate and rainfall as varied as one can find in the entire temperate zone. Of these three principal streams the Ohio rises in the Alleghany mountains. Its waters come, some of them from southern New York state, some from Pennsylvania and

THE CONSERVATION OF WATER

West Virginia, some from eastern Tennessee, North Carolina and northern Alabama, — but from every source except from Ohio and Indiana they come from steep hill and mountain sides which slope precipitously down to the valleys and the rivers.

The Upper Mississippi on the other hand rises in a broad and gentle valley. Its headwaters, about Lake Itasca, are in a wooded plain of gentle slopes, surrounded by a rim of rock which makes the entire headquarters region a rain-storing plateau, and over which they descend swiftly in numerous falls. All the tributaries, the Wisconsin, the Illinois, the Minnesota, the Des Moines come from the same gentle slopes and pour their water more slowly into the parent stream.

But the Missouri varies widely from both of these. It rises in the western edge of the Great Plains and in the foothills of the Rocky Mountains. Out of the beautiful Gallatin range and its neighbors flows the river, to course across the semi-arid west, cut its chang-



TOO CLOSELY GRAZED FOREST

TOO CLOSELY GRAZED FOREST

Great herds of sheep and cattle range through the National Forest Reserves. Without supervision these flocks are grazed too closely, and they rapidly destroy the herbage and leave the forest soil to be dissolved and washed away. Proper supervision by the forest rangers, instituted by Forester Gifford Pinchot, prevents this overgrazing, the herbage is maintained, and the forest floor remains a good storage reservoir. Too close grazing also kills the young trees.

FLOODS AND FLOOD PREVENTION

ing channel through a bed of friable alluvium, and come at last to join the Mississippi. On the whole upland of the Missouri the rainfall averages but fifteen inches each year, and this comes at such times that much of it benefits the river very little. During the summer season the ice and snow in the mountains melt and feed a very considerable flow into the river; but the rain that makes the prairie streams, such as the James, the Little Missouri, the Platte, begins slowly in April, and is soaked into parched ground and does not until May become violent. Then through May and early June it tears swiftly into the river bed, sweeping with it the loose and friable earth. Filling its bed to overflowing it pours along, a turbid flood, doing enormous destruction. As quickly as it came the flood ceases, the prairies go dry and the coulées are sunbaked; and the Missouri, which has been a raging flood, becomes a little and inefficient river. Along the banks of this stream are produced fabulous crops which seek markets lower down — but the insufficient

THE CONSERVATION OF WATER

channel at harvest time renders transportation almost impossible, and makes the river useless. All through the summer the clouds sweep over the shadeless plains without dropping moisture upon them, and the Missouri dwindles away until the fall rains begin to swell it just as the ice is forming.

The rainfall upon the Ohio is far different from that upon the Missouri. Averaging about forty inches, it falls in places seventy inches in a year, and produces enough in the river to maintain a beautiful boating stage every day in the season. Unfortunately the greater part of it goes to waste. The heaviest rains on the Ohio begin in February or March, when the hillsides are frozen and the earth can absorb nothing. Usually the hills are at this time covered with snow which melts under the rainfall, and the snow and rain together sweep with amazing speed down the hillsides and fill the rivers. As they rush on they tear out the soil and carry it with them, and before they reach Pittsburg those which come out of Pennsyl-

FLOODS AND FLOOD PREVENTION

vania are already deep yellow-brown with the burden of stolen earth.

All of the valley about Pittsburg is strewn with mills. Steel furnaces and iron mills border the streams, and stores of coal and coke and the bright fires of coke-ovens line their banks. The livelihood of hundreds of thousands of men, and the continuance of industries in every part of America depend upon the activity of these mills. Night and day their fires burn, night and day men turn the great ladles which spill burning slag down the hillsides, or open the channels and let the oily, molten iron run flaming into pigs. Night and day the roar of ceaseless activity, the crash and hammer of the steel trade goes on — until the flood comes, and the waters creep up out of the banks of the streams.

Inch by inch they rise, rod by rod they spread back over their banks. First the casting floors and the railways are overflowed; then the furnaces are extinguished. Men are driven from work, and then from their homes. Boats of

THE CONSERVATION OF WATER

coal, sheds, furniture are swept away. Stores are invaded. Industry is at a standstill and starvation faces the workingmen out of work. Able at best to live but from hand to mouth, the energy and the charity of a nation are required to provide a living for those thus held from work by the flood.

Three times within two weeks one has seen, in Pittsburg, the two streams which form the Ohio there, rise out of their banks, until they stood thirty feet or more above their low water level. At the first sign of the flood the shipwrights were hastily summoned and the basement openings of stores in the lower sections of the city were caulked with oakum, to withstand the floods. As the waters rose the stores were closed and the first floors caulked. But, in spite of this, hundreds of thousands of dollars, and even millions, were lost in this invasion by the rivers of several blocks of the city land.

Lower down the Ohio receives the Kanawha, the Big Sandy, the Licking, the Kentucky, and

FLOODS AND FLOOD PREVENTION

becomes even more destructive. It sweeps back over its farmlands to its bluffs and invades all the neighboring valleys and their towns. At Cincinnati it rises sixty-five feet vertically, and floods streets which at low water are sixty-five feet above the level of the river. This immense torrent, seventy feet deep, a mile wide, sweeps along at a gait of nine miles an hour, wrecking steamboats, sinking coal barges, and doing more damage than it can pay for in a whole season of service.

A six-story warehouse built on the bank of the river at Cincinnati when the water is low, would be entirely overwhelmed and hidden from sight at high water; and a shallow steamboat might sail safely over its roof.

Below Cincinnati the Ohio receives the Tennessee and the Cumberland, two mighty rivers, either of which is as destructive as the Ohio above them; and the three pour out into the Mississippi, to go on damaging property all the way to the Gulf. For it is the Ohio which makes the grand floods of the lower Missis-

THE CONSERVATION OF WATER

ssippi. The volume of water contributed by the Ohio is nearly half of all that goes into the Mississippi, and it nearly all comes in flood time. The Missouri and the Upper Mississippi contribute long, gentle swells, but the Ohio sends precipitous and destructive waves one after the other.

A single flood in the Missouri valley in 1903 is estimated to have done not less than \$25,000,000 damage. It is doubtful if the Ohio does not do this much damage or more every year in its own valley. A flood in the Seine in France in 1910 is said to have cost that nation \$200,000,000 and one in the Loire in 1851 made a total loss of \$67,000,000.

These immense sums show the actual property loss from the waste of water, and it is only that with which we have reckoned heretofore. So it is against this alone that we have directed our protection against floods. We have never until now considered water as a resource. Saving the water to use when we need it, preventing loss by preventing floods,

FLOODS AND FLOOD PREVENTION

establishing, as it were, a savings bank in which to desposit in the rainy season an account on which to draw when we are hard up — has hardly until now occurred to us. Content to let the floods exist, we have devoted ourselves only to making them keep within reasonable bounds. We have built stone walls and earthen levees against them.

It is in the valley of the Lower Mississippi that one sees these levees in their greatest size and their most complete system. There for one thousand miles, from Cairo to the sea, the river flows through a bed which winds from side to side of a valley between bluffs forty miles apart. When it rises out of its banks and overflows it fills this entire valley, forty miles wide, and sweeps on over cities and through forests to the sea.

More than a century ago the French began building earthen ramparts to hold the river off the land about New Orleans, and this work has gone steadily on until to-day, when there exist fourteen hundred miles of levee along

THE CONSERVATION OF WATER

the river, and thirty thousand square miles of land, the richest in America, is no longer overflowed.

These levees are but earthen banks, sometimes two hundred feet thick at the base, sloping up about one foot for every three horizontal, and so rising sometimes twenty-five feet above the top of the river bank. Where the banks are stable they are close to them, but where the banks are caving the levees are set a mile or more back and the land in front is left to be devastated. These levees are built from earth by mules and scrapers, and the whole of them have cost the nation more than \$60,000,000, two-thirds of which the people along the river have contributed in taxes and the rest of which has been furnished by the nation. There is nowhere else in the world so magnificent a system of ramparts, so great a system of defense against so mighty a river. Year after year the yellow torrent rises against them. Year after year he gnaws at them, endeavors to overtop them, seeks to find seepage



A LEVEE AGAINST FLOODS

A LEVEE AGAINST FLOODS

This view, taken near New Orleans, shows the earthen rampart which shuts out the Mississippi from the land. Owing to the floods, uncontrolled at headwaters, the river is for a considerable part of the year above its banks, and but for these levees would cover an area of 30,000 square miles between Cairo, Illinois, and New Orleans. Such levees are only makeshifts, easily broken. The real cure is in the storage of the flood at headwaters.

In a levee such as this at Hymelia — not far from the scene of this picture — a crawfish dug a hole through the earthen wall in time of flood, in 1903, causing a crevasse that did more than a million dollars' worth of damage.

FLOODS AND FLOOD PREVENTION

or crawfish holes through them with which to make a crevasse. And then, in a night, when the victory against him is won, he finds a weak spot; the soft earth slumps away; there is a rush and a roar of waters; instantly the crevasse is there, and thousands of men, equipped with every weapon known to man for the staying of floods, can make no headway against the invading monster.

At Hymelia, a sugar plantation in Louisiana, the flood of 1903 broke through a levee in the night and before it was stopped did damage amounting to \$1,000,000 to the sugar plantations for miles around. In the same year the levee at Hollybush, Arkansas, broke and flooded fifteen hundred square miles of land, from which the people took to the trees and awaited the coming of rescuing boats. Hardships indescribable follow such a flood. Cattle are drowned, farms are ruined, buildings are lost. The poor people must begin again with nothing to establish themselves. If we had no other evidence we should know that these protective

THE CONSERVATION OF WATER

levees, necessary now and to be maintained as long as they are necessary, are but a makeshift at which the river laughs in mockery, and are not the real solution of the problem of floods.

Yet even greater than its actual destruction is the cost of the flood to us in loss of waterpower. Waterpower, as we shall see in a later chapter, is due to what is called a "head" — a difference in level between the water on the upper side of a dam and that on the lower. The water descending through this distance in a tube or penstock passes through a horizontal wheel called a turbine and revolves it much as wind revolves a windmill. The weight of the column of water resting on this wheel, and the speed of its descent, provide the power, and the weight of the column depends upon the height of the "head."

When floods come rapids which are very swift and even abrupt at low water become insignificant obstructions under the tremendously increased volume of water. Low dams,

FLOODS AND FLOOD PREVENTION

instead of being able to hold back the water, become merely riffles in the bottom of the stream. No head is left, as the water below is as high as that above, and even if the power house is not "drowned out" the power is all lost while the flood is passing.

So all this valuable water goes by without being used, and, while it is passing, the costly plant, built to employ it, is earning nothing; and, unless a duplicate steam plant is standing by to take up the work, the mills dependent upon the power must shut down and their employes be thrown out of work. But if there is a duplicate steam plant to do the work, then that must stand idle when the waterpower is used. There must be twice as much machinery as is enough to do the work; and the factory must earn, and must charge consumers for the extra investment.

When the flood has passed and the river has come down to a normal level the head is reestablished and the machinery turns again. But now only a few weeks pass by before the rains

THE CONSERVATION OF WATER

have altogether ceased, summer has come, soil moisture is being evaporated, the river is diminishing, and for lack of that great, wasted volume of water that went out with the flood the mill begins to work feebly. Soon it must lay off men, or start the "steam supplement" again. It is easy to see that from the point of view of the mill proprietor a "normal water" with neither floods nor droughts in his river is desirable; and his view is shared by his employed.

A ready illustration of this is given by the Connecticut river, the principal stream in New England. The Connecticut rises in northern New Hampshire, many hundred feet above the sea, and flows southward, receiving many tumultuous tributaries. It has its rise in several lakes which offer an excellent beginning for a big storage system, and these we shall take up later. Each of the principal rivers flowing into the Connecticut is employed to drive factories — the Deerfield, Miller's river, the Westfield, the Chicopee, are all lined with mills which depend upon them; and the main

FLOODS AND FLOOD PREVENTION

river at Bellows Falls and Holyoke and at other places furnishes very large power.

The lower part of the river, from Hartford to the sea, is a navigable channel having a low water depth of ten feet through which vessels ply between Hartford and New York. The people of Hartford seek to obtain here a channel eighteen feet deep.

In the summer of 1908 the low water season which always affects the Connecticut at that time of year set in and continued for several months. Absolutely without rainfall, entirely lacking in storage, the Connecticut went practically dry. There was not water enough in the river at Holyoke to use in the industrial processes, and none at all for power. Steam supplements could in some cases supply the power but they could not supply the water needed in the mills, and one after another the paper mills shut down and left their employés idle and suffering.

In the fall rain came, but this rain and melting snow in the early spring filled the river so

THE CONSERVATION OF WATER

full that they overflowed the plant at Holyoke, drowned out the fall, and again temporarily rendered the power idle and shut down the factories. Flowing scarcely one thousand second feet at low water, the river rose until at Hartford it was twenty-six feet deeper than at low water and discharged 144,000 second feet. It spread out over the meadows and did hundreds of thousands of dollars' worth of damage. But worst of all it wasted invaluable water. Had the flood which went to waste in one day past Hartford been saved and used in June it would have kept up an eighteen foot channel to the sea through a whole month. And had that which went to waste in a week been saved and used in the dry season it would have been enough to keep the channel eighteen feet deep all through the summer and fall, until the rains came again in November.

But more than that, taking it off the crest of the flood would have allowed the Holyoke mills to keep running through flood time; and adding it to the low water would have kept them busy,

FLOODS AND FLOOD PREVENTION

then as well. This saving of the water is the real method of preventing floods — not to run it swiftly to the sea, but to confine it at headwaters and save it to use when it is needed. We must establish a savings-bank account, and store the water in it. It will pay abundant interest while it is stored, and the capital can be drawn upon when it is needed. We may see this method applied successfully in many places, and for a good example we may look at the Neisse river in Prussia, Germany, and Austria.

✓ The Neisse river rises in Bohemia, a province of Austria near the German frontier. It is formed of a number of little streams, chief of which is the Goerlitzer Neisse, which come out of densely wooded hills and beautiful mountain valleys. It flows by a number of prosperous villages in which the river turns many mill wheels, and emerging from Austria crosses Saxony and enters the Oder in Prussia. Thus it involves three states, Bohemia, Saxony and Prussia, of two different empires, Austria and

THE CONSERVATION OF WATER

Germany. There is no one government which has authority over it, and besides being difficult to control it appears to be an outlaw which no one authority can take in charge. It is like the Tennessee, which rises on the borders of Virginia and the Carolinas, flows through Tennessee and Alabama and Kentucky and adds to the great damage done by floods in Missouri, Arkansas and Louisiana. The states which suffer are not those in which the damage originates. So when, on the 29th of July, 1897, the Neisse suddenly swelled to thereto unseen proportions, overran its banks and poured a destructive torrent down its valley, though the mills destroyed, the homes invaded, the villages driven from their dwellings and destroyed were mainly in Prussia and Saxony, the source of the damage lay in the denuded hillsides of Bohemia whence the forests had recently been cut away.

What then, to do? Bohemia could not act to aid Prussia or Saxony; Germany could not pay taxes to Bohemia to pay for improvement

FLOODS AND FLOOD PREVENTION

and control; and yet nothing was more certain than if the conditions continued the valley might expect frequent repetitions of the destructive flood, and might expect that discouraged people would abandon their homes and move to more favored localities.

In this emergency the mayor of a little village, Reichenberg, involved in the catastrophe, called a meeting of representatives of all the governments, and of all the villages and industries involved. Four hundred men, vitally concerned with the correction of the river, met at Reichenberg in response to this summons. They came to look upon water in two ways — first, as a destructive force which must be curbed; but second, and much more continually, as a public servant capable of doing valuable work, who was escaping from their control.

They were not long in arriving at a conclusion. Following a happy suggestion they formed a “Genossenschaft” or Fellowship, known in law as a corporation “not-for-profit”; and in

THE CONSERVATION OF WATER

a true spirit of fellowship all the interested parties entered this body. That is, they formed, and their government allowed them to form, a fellowship for mutual and public advantage, to undertake a work the organized government had no power to do.

Engineers engaged by this fellowship made a thorough survey and planned six immense dams across the upper valleys of the Neisse. Tunnels through hills would divert practically all the little streams into the basins above these reservoirs. The whole work of building six dams and collecting the water would cost \$1,500,000.

The members of the Fellowship considered this problem. It was a large sum of money for the villagers to raise; and they had no authority to tax anyone or to compel payments. But their plan was a good one and each government could do for this little group what it could not do for a rival government. Thus the agricultural and forestry departments of the Bohemian and Austrian governments con-

FLOODS AND FLOOD PREVENTION

tributed liberally, half a million dollars that did not require to be paid back, and half as much more which bore no interest. Saxony and Silesia, which had suffered from the flood, contributed altogether \$100,000 spread over ten years. The rest of the sum was raised on bonds from the banks, and a levy was made upon the waterpower developed by the storage of water (which we shall describe later) sufficient to pay the interest and eventually to retire the bonds, without taxing any value which was not created by the improvement.

The dams which were thus built in the valleys of the Neisse are not crude wooden, or unfinished concrete affairs, blotting the landscape. Instead they were built massive and beautiful, after the German method. With their curving crests handsomely decorated, their façades graceful and dignified, and their banks above low water planted with grass and overshadowed by trees, they make a great addition to the mountain landscape. Stocked with fish, at all times holding abundant water (yet with ample

THE CONSERVATION OF WATER

reserve space for flood times) they furnish recreation places for the inhabitants and attract tourists who spend much money in the neighborhood. The millers have a steady power which contributes to the steady employment of the people and reduces their cost of living. The danger of a repetition of the flood is gone; and the entire result, the turning of the waste water into use, the developing of a resource out of a danger, has been carried through at no cost to anyone because a patriotic and long-headed mayor and some country-loving citizens got together in Fellowship and without pay and without profit carried through a beautiful public work.

CHAPTER III

STORAGE

The Mayor of Reichenberg had the right idea of the first step in the Conservation of Water. The waste water must be stored. We must secure more of Ezry Perkins' land and turn it into water farms. Water at the wrong time is a destructive nuisance. Water at the right time is a public asset of great value. The moral is easy to see. We must hold back the inopportune flood and release it when it is needed.

Nature does this for us in a remarkable degree. There is no steadier or more remarkable great river in the world than the St. Lawrence; and this is true because the Great Lakes, which feed it, are the largest and finest reservoirs of fresh water in the world. The torrents of water which pour into them in rainy seasons do not sensibly affect their level or increase the St.

THE CONSERVATION OF WATER

Lawrence by more than a few feet; and a prolonged drought finds the immense reserve in them still feeding the outlet stream with an equal volume. It is only through long periods of years that their level fluctuates, and even that cannot be entirely attributed to the rainfall and drought.

We cannot construct such reservoirs as these upon our other rivers, but we can store larger volumes of water upon them than we have ever contemplated doing, and we shall find this matter of water storage — of water farms and white coal mining — growing larger in our life for many years to come. Every acre of land that we irrigate demands water stored in reserve above it. Every waterfall which we turn to electricity demands a reservoir which will carry it through drought and preserve it through flood. Every navigable channel demands an adequate supply of water in dry seasons, and demands that the floods be kept back from it; and every other use which we have for water contributes to this demand.

STORAGE

The basis for such storage and for any development of water is a careful survey and measurement to determine how much water falls upon the watershed of each river, how much of that makes its escape by river, and how much can be held back in available reservoir sites and used profitably. To this work the Government has already given much time and money, and while the observations and records are not complete they constitute a large and valuable mass of information. We have now records of rainfall in all parts of the country, carefully districted, so as to cover the headwaters of every principal stream and many little ones, and showing in detail, week by week, how much rain falls in excessively wet, in very dry, and in normal years, and how often these variants may be expected.

Measurements of streams have been made with equal care, and recorded in "second feet" — that is, in the number of cubic feet of water which run past a given point each second of time. It is possible now to tell with accuracy

THE CONSERVATION OF WATER

how much water from a given rainfall runs into the rivers in the spring, when the ground is already saturated, and how much in the fall, when the ground is dry. We know why the Ohio with a given rainfall in the spring produces at once a sharp flood, whereas in August the same rainfall scarcely produces a change in the river. The average "run-off" which is the percentage of rainfall which runs in the rivers, is figured very closely, and in addition to these figures maps show the exact drainage area of every tributary stream.

From these figures it is possible to compute at any point on a river the average or normal flow, the amount of water which would have to be stored above that point to hold it down to that figure in wet seasons, and released to bring it up to that figure in dry seasons. It is possible to tell how much can be used in an average year, and how much reservoir capacity will be needed to save the surplus of very wet years to use in very dry years. Even with this we do not hope perfectly to normalize

STORAGE

any river; but it is possible to reduce its fluctuations to a negligible quantity and keep it always at something less than a "bank full" stage.

A reservoir site having been selected in which with a minimum of expense a maximum of water can be stored, the ground must be obtained, houses cleared away, everything which could defile the water removed, and the bed reduced to good condition. From both sides of the surrounding hills a retaining wall is built out to the dam-site. The dam-site must, if possible, be so selected as to provide a rock foundation, and as narrow a dam as it is possible to find a site for. Then upon a rock foundation or upon hardpan, concrete, stone, sometimes only earthen fill, are heaped up, to the necessary height. The designing of concrete dams is a matter of great engineering importance, and the problem of the relative factor of safety, the provision against the overturning of the dam by the pressure of floods behind it, is one on which engineers differ widely.

THE CONSERVATION OF WATER

The dam must be provided with a spill-way in which floods may begin to discharge before the crest is overflowed. They must have releasing gates or sluices through which all the water may be drawn out as needed. If they are in navigable streams they must be equipped with locks in which vessels may pass between the upper and lower level. And in many cases they are provided with steel attachments called flashboards which may be raised as the floods recede, increasing the storage capacity of the dam, and lowered to release surplus water ahead of an advancing flood which it is necessary to provide for. In each dam provision is made for the development of power at the outlet due to the head of storage behind the dam; but this power is not as reliable in amount as power from the same stream a distance below the reservoir.

In the cost of such storage there are many things to be reckoned — the cost of the ground, sometimes the removal of whole villages, the moving of cemeteries, the preparation of the



A WATER FARM

A WATER FARM

This is the immense artificial lake behind the Roosevelt Dam, of the Salt River Irrigation project above Phoenix, Arizona. The dam was built by the United States Reclamation Service. This is the largest single reservoir in the world. The water from it irrigates 200,000 acres of desert land, beside creating power. The land under the water, once valueless, thus becomes a large contributor to the national wealth.

STORAGE

ground, the actual construction of the dam and retaining walls. Such costs vary widely according to locality, and they are usually expressed in relation to millions of cubic feet of storage capacity behind the dam. Thus on the Mississippi the reservoirs have cost about \$14 per million feet. In commercial storage the cost is often \$100 per million feet. Even twice that amount is not unusual in old settled parts of the country, though in New England storage can usually be secured for \$150 per million feet.

That is the whole secret of the water farm. Wherever there is land in a valley capable of being made part of a storage basin by the erection of not too costly a dam, and where there is a drainage area of sufficient capacity above, that farm becomes of value in proportion to the depth to which it can be flooded and the distance the water falls in running down to sea level.

Ezry Perkins alone could never develop and use the storage capacity of his farm. The res-

THE CONSERVATION OF WATER

ervoirs of a whole river must be developed by some unit organization, public or private, like the Fellowship of the Neisse. But when it is done the water stored will return the cost of the dams and of the land at the rate of thirty cents for every million feet of stored water, for every foot it drops through turbines on the way to the sea; — that is to say, \$30 a year for every acre one hundred feet above the sea which can be flooded twenty-five feet deep in water; or \$150 an acre-year for the same quantity at an altitude of five hundred feet.

Disregarding the Great Lakes, which are Nature's reservoirs, the largest water farms in the world are the basins at the head of the Mississippi river in Minnesota, created by the federal government to reduce floods and to improve navigation. They are an indication of the way we must go, for in time we must treat every river in America as the headwaters of the Great Water have been treated.

The Upper Mississippi rises in a plateau region in northern Minnesota, where it is fed

STORAGE

by innumerable lakes, and surrounded by a great area of swamps cut by small and crooked rivers. Much water which falls upon this region naturally flows off quickly at flood time, and the rest lies stagnant in the swamps, useless for any purpose in the river. Down from this plateau the river flows in a series of rapids culminating in St. Anthony's Falls at Minneapolis. Below and between these rapids the river is navigable except in extremely dry summers. In the old days the river at St. Paul had less than one thousand second feet discharge at low water, and the channel was often less than one foot deep. The power at St. Anthony's Falls, imperfectly developed, was shut down in floods, and almost useless in late summer.

Among the lakes at the head of the Mississippi the government engineers selected the largest, Leech, Winnibigoshish, Cass, and Pokegama, and some smaller ones as reservoir sites. These, with the surrounding land, were set aside by Congress, and low dams, none of

THE CONSERVATION OF WATER

them more than fourteen feet high, were set across the outlets, equipped with bear trap gates — regulating gates to allow the water to flow out as needed. It required several years of accumulation to get a “working capital” of stored water in these reservoirs, and they can be drawn upon through several dry seasons without giving out. The low wooden dams have been replaced by concrete at a slight cost, and the whole system now retains in flood time 93,000,000,000 cubic feet (enough to cover 2,000,000 acres of land one foot deep). This is the largest artificial storage in the world. The result of it has been to keep the Mississippi at St. Paul never less than three feet deep in the lowest water and usually four feet, and to take the crest off the spring floods. At the falls it has rendered all the waterpower steady and extremely valuable. Engineers estimate that at St. Anthony’s alone it has benefited the manufacturers an amount in excess of \$500,000 annually. No return from this benefit is now made to the government, but it is certain that

STORAGE

before long steps will be taken to secure a return from this which will repay the cost of the reservoirs.

Reservoiring is very necessary for the prevention of floods, for the improvement of navigation, and for the development of power. But it is equally important for irrigation; and in the west, where irrigation projects are carried on, we find some of the largest storage dams and some of the largest reservoirs in the world.

One of the great rivers of the west is the Flathead, which becomes the Pend d'Oreille, and which in turn helps to form the Columbia. This is a magnificent stream, flowing at times very swiftly, at times in a still, deep, navigable channel. It has on its upper course one of the most beautiful lakes in the world, Flathead Lake, a body of glacial water forty miles long and fifteen miles broad, surrounded by lofty and snow-clad mountains capped with glaciers. Out of this flows the river to furnish water for power, irrigation, and navigation. These three

THE CONSERVATION OF WATER

interests properly conserved do not interfere with each other.

An acre foot of water properly applied is sufficient to irrigate an acre of ground through a year. It is the equivalent of twelve inches of rainfall applied at exactly the right time and in the right amount and under perfect control. Flathead Lake contains a surface of nearly 400,000 acres. A dam five feet high above low water level at the lower end, not raising the water above the ordinary high water level, would store 2,000,000 acre feet, or an amount exactly equivalent to all the reservoirs of the Mississippi. This would not alter or deface the shore line, render the lake less beautiful or do anything injurious; but it would add to the Columbia in dry times water enough to irrigate copiously and too abundantly one million acres, or under proper restrictions two million acres of rich desert land.

Storage for irrigation, the enormous dams constructed to hold back the floods, we will consider again under the head of irrigation.



A MOUNTAIN RESERVOIR

A MOUNTAIN RESERVOIR

This lake, which is a typical reservoir site, shows the ill effect of the carelessness which has always prevailed in our care of our timber until the government Forest Service took hold. Over a large area immediately above the lake the forest has been entirely destroyed by fire, and the hillside left bare. This lessens the storage over the lake, lessens the value of the forest, and allows the soil to wash down into the lake and slowly fill it up. It is the Forest Service policy to replant and protect such hillside to guard the reservoirs.

STORAGE

It is enough to show here the need and the character of this water farming which is so necessary to irrigation farming in the west. In time on every river in America the work will be undertaken, and every lake will have its boundaries fixed, its outflow controlled by proper mechanism. But this is not the only form of water storage. The water farm must have a wood lot. The hillsides above it must be planted with trees to facilitate the preservation of the water supply, and to prevent the basin from filling up with washed soil.

Everyone who has lived in the country and has used a well knows that water is stored in the earth as well as in lakes and ponds. Those who live in a prairie country know that when trees are planted about a well this storage increases and the well collects more water. The forest affects the run-off and the storage of water in many ways.

The forest shades the moist earth beneath it from the direct rays of the sun and so prevents evaporation. A pan of water set beneath the

THE CONSERVATION OF WATER

trees will only evaporate a third as fast as one set out in the open field. Then the earth beneath the trees is formed of vegetable mold, weathered rock, finely divided soil mixed with decayed leaves and twigs, to form a soil called humus, which absorbs water like a sponge, retains it, and gives it out slowly, drop by drop. And in the third place, the roots of the trees working continually in the soil, open little passages through which the water runs deep into the earth, forming subterranean reservoirs from which flow springs, to appear far down the hillsides.

So when the rain comes down upon the forest it does not run off quickly as from bare ground, but for the most part is held in check by the trees and the soft earth. After the ground is saturated, and the woods are unable to retain more it runs into the streams as rapidly as from barren ground, but not until a large amount has been placed in forest storage. The roots bind and consolidate the earth even then so that no earth is carried away by the

STORAGE

running water. And when the rains have ceased and the barren ground has gone absolutely dry, when the water-courses fed by bare and open ground have not a drop left to flow in them, the forest soil by slow seepage still gives out its treasures, and the hillside springs, fed by the deep reservoirs, still flow.

But the forest is able to do even more than this for the supply of water in our streams. Much of the rain which falls beneath the trees dissolves from the soil the plant food which the trees need and is carried upward through their veins to envehicle this nutriment. The trees absorb much of the water and all of the food, but the rest of the water is breathed out through their leaves, in what is called transpiration, and in this process a great quantity escapes into the air. This produces a coolness in the air over the forest which is felt by balloons, sometimes three thousand feet above the trees.

Rain is caused by the cooling of the moist vapor in the air. When a current of water

THE CONSERVATION OF WATER

vapor, invisible in the sky, encounters a cooler current it condenses and forms clouds, and if the cooling and condensation continue these further precipitate into rain. On the western prairies, often during long dry spells, rich currents of unseen water vapor are sweeping overhead, but the hot plains prevent its cooling and its precipitation; and many attempts have been made to force this result by firing cannon and bombs.

How much more simply the forest does this! The cool air over the forest chills and condenses the passing moisture and causes it to fall upon the trees. Experiments actually carried on for thirty-three years in a forest of eighteen thousand acres in France show that for every thirty-six inches of rainfall in the center of the forest there was but thirty inches in the edge of the forest and twenty-four inches in the open fields ten miles away.

That is why the destruction of our forests has been so destructive of our river channels; but there is a greater reason. For the roots of

STORAGE

the trees bind the soil and prevent erosion, and when the trees are cut away the water rushes pell-mell down the hillsides into the channels, carrying with it sand and gravel. It runs away to the sea with the light and fertile elements, and leaves the sand and gravel to block the channels and prevent the use of the water for power and navigation.

So the Conservation of Water requires not only the establishment of water farms, of big reservoirs, but of tree farms as well — properly conducted forests upon the hillside and upon the plain; and it is one of the happy features of the work that these forests which add to the value of waterpower also furnish the material which is manufactured into useful articles at the power-sites.

We have here then the big, complicated problem of our rivers — rivers which flow through many states and affect both local and national things. To prevent floods, to prevent the loss of electrical energy, to preserve navigation, to permit irrigation, to supply our cities

THE CONSERVATION OF WATER

with domestic water, the public must eventually reservoir all the streams; and the states to add to this work and to secure a wood supply must plant forests about the headwaters. Some way must be found, then, by which this work can be carried on, and the money benefit which accrues from it may be made to bear the burden of the expense; and by which in the end the public, which owns the running water in the streams, may secure the ownership and control of these great public works which make the running water efficient.

We find in the state of Wisconsin a long step taken toward this work, and a great example of reservoiring and reforestation of headwaters undertaken.

A generation ago this state was covered with an immense forest containing a magnificent stand of white pine, spruce, and fir timber. Into this forest went the destructive breed of lumber men who have wasted such a large part of our heritage. They cut the heart from a small part of the forest and sent fire sweeping

STORAGE

through the rest, burning hundreds of thousands of acres of primeval growth.

Under its unbroken forest Wisconsin lay a land of treasure. Most of its soil is rich; its rivers run swiftly and are full of power; and their lower reaches offered fine water for navigation. Along the east shore extends Lake Michigan, along the west the Mississippi, and Lake Superior is on the north. From a little area of high ground in the north central part of the state flow all the streams which reach these several great waterways. Though there is no mineral fuel in the state its water powers seemed inexhaustible, drawing their summer water from thousands of ponds in the source region. It seemed a state destined to become among the wealthiest in manufactures of all those manifold things which are made from the forest.

At first only the lumber men used the waterfalls, and the logs that drifted to them were sawed and sent in rafts to market. Steamboats ascended the rivers and brought in and

THE CONSERVATION OF WATER

carried out freight. Railways crossed the state and charged low rates to compete with the waters. But as the forest burned away and was destroyed the friable soil of the upper regions washed into the ponds and the streams became less regular. Sand filled the rivers and destroyed the channels. The enriched lumber men, caring nothing for the future, but satisfied with the present gain, abandoned the burned-over land to the state and deserted their fallen dams.

Wisconsin should be rich. Her furniture factories, standing beside the rivers which bring the lumber to them, should be among the largest in the world. Her paper mills, with an unfailing supply, should contribute an unlimited amount to the immense demand. Her toy factories and her boat works should be known throughout the world. But instead Wisconsin found her forest almost exhausted, her rivers running wild, her navigation lost.

That was the state of affairs when a young man came to the state from the forest schools



CUTTING TIMBER IN A NATIONAL FOREST

CUTTING TIMBER IN A NATIONAL FOREST

This shows the method employed upon government and upon well-managed private forests, of cutting only the mature trees, leaving the young and half-grown stock to reproduce the forest. The slashings, which would otherwise be a source of danger from fire, are gathered in piles and at a favorable opportunity are burned. By this process the forest is preserved and the forest cover remains a natural storage place for the rainfall.

STORAGE

of Germany, a man who had studied "fellowships" in Switzerland and in Bohemia — "fellowships" by which common, ordinary men, not accustomed to handling capital, give their time and their energy to developing public enterprises for the public good. This young man, Mr. E. M. Griffith, who came to be forester, by recalling and combining the scattered companies of the forest army has established them as a defensive force which will restore the state. Up there in the central highland, whence all his rivers rise, he has established his stronghold, and there he has determined to gather a reserve of three million acres of trees. All over the state are — or were — isolated companies of the old stalwarts, ten acre and forty acre groups of pines or of cut-over ground belonging to the state. Two hundred thousand acres of this was turned over to the forester and he has been selling it off as agricultural land, and with the money for every acre buying and planting two or three acres of the cheap, cut-over land in his new fortress.

THE CONSERVATION OF WATER

So he is assembling his force. Already there are nearly four hundred thousand acres in it.

It was not long before this reassembling of the army and the effect of it upon the rivers attracted the attention of the mill-site owners at Stevens Point and Grand Rapids and all the other towns along the Wisconsin river on the head of which were most of the new reserves.

The state of Wisconsin is prohibited by its constitution from undertaking public works. So a new law was passed for the mill owners creating a corporation — *a corporation not-for-profit*, something almost unheard of in America. It is called the Wisconsin Valley Improvement Company, and has a paid-up capital of one hundred thousand dollars, on which it is allowed to earn six per cent. The stock of this company must be offered to every power owner on the river, in the proportion which his own power bears to the whole power of the stream. If he does not care to buy, the rest divide it among themselves, but at any annual meeting he can come and demand his share, at par.

STORAGE

The corporation, subject to the control of the forester, has the right of eminent domain over ponds and lands — lands suitable for water farms — in the source region, and the right to use ponds in the forest reserve. The forester sets two monuments. They cannot raise the water above the one nor draw it below the other. This insures the beauty of the forest, which is to be a great state park. The corporation builds dams out of its capital and establishes men to work the sluice gates.

Meanwhile the State Railway Commission has surveyed the valley, determined the present strength of every power, and the extent to which it is improved by the use of storage. They add up the cost of operation and the six per cent interest, and divide the sum per horsepower of improvement on every power owner whether he is a stockholder in the improvement company or not. That is, they make a tax of it. The corporation can issue no stock without special permission and for money paid in. It can do nothing but improve the river by stor-

THE CONSERVATION OF WATER

age. It pays its own way and nothing more. And the state can buy it at any time for the actual amount spent or for its physical value. There is no chance for a monopoly there.

Now let us see what the forester has done for Wisconsin with the aid and co-operation of the mill men. There is so far developed four billion feet of storage, and surveys are made for twenty billion. The value and efficiency of every power on the river is already doubled. Instead of shutting down, or buying coal in the low water season, as the mills on other rivers do, those on the Wisconsin go ahead on their stored water. The lower river, which has so long been unnavigable, is soon to become a deep and useful stream, reducing freight rates in a large territory.

And to indicate that the benefit is well understood, the forester has been called upon by the mill owners of the other big rivers, the Flambeau and the Tomahawk, the Chippewa, the St. Croix, the Wolf, the Fox, the Peshtigo and the Menominee, to work out the same system for

STORAGE

them all; and within a short time not only will the three million acre forest reserve cover the head of all these streams, but their thousands of ponds will be turned into reservoirs, the rivers will have ceased their floods, there will be work at full time all the year round in every water mill in the state — which means in a majority of its great industries; the state will be saving many millions a year on its coal bills. Into the state treasury will come an increasing revenue from the forest tract; and an increasing volume of paper wood, furniture wood and lumber, drifting down the stream to the biggest paper making towns in the world. From the factory doors the finished products will proceed on canalized and regulated rivers, to the lakes and to the Mississippi, to Chicago, to St. Louis, to the Gulf and to Panama. The whole state benefits by this. And what is best, no man suffers a loss.

Wisconsin now has one hundred and twenty-five thousand horsepower developed on her streams, and by the old method could develop

THE CONSERVATION OF WATER

perhaps five hundred thousand horsepower. By the new system she will have at least one million horsepower worth now, as power goes up there, not less than twenty-five million dollars a year and in time to be worth much more — and worth it partly because, thanks to the inexhaustible forest reserve and the great private tracts which are to be worked in system with it, the mills will have a perpetual abundance of the raw material for their goods. And of this sum a full half will be due to the reservoirs.

That is the way the rest of us must travel; and in the end we will find not a bill of expense, annually renewed by flood and drought, but a steady income, from dividends regularly declared, on all we invest on the wise conservation of our water supply by forestry and reservoir construction.

CHAPTER IV

MUNICIPAL SUPPLY AND THE PURIFICATION OF RIVERS

With a national indifference to our neighbors' well-being nearly every city in America pours its sewage and drainage into some running stream, regardless of the consequences to those who dwell farther down the valley. With an equal indifference to our own well-being many cities pump their domestic water supplies from these same running streams and send them through their mains into their houses without purification or alteration. Those cities which seek to get away from this barbarous fashion find themselves confronted by one of the most perplexing situations in the whole story of Conservation. There is but one way, apparently, to raise a crop of pure water. That is for each city to establish its own water

THE CONSERVATION OF WATER

farm and grow the product under watchful supervision.

In the same way that individual cities and states long fought against adulterated and unhealthy food products vainly and then combined in a national pure food law to remedy the situation universally, so we shall in time become discouraged with endeavoring to remedy this situation locally and shall pass a national pure water law, which will make it impossible for any city, factory or individual to corrupt a running stream, and will make the water in our rivers clean, healthful and useful. Every water farm will be a source of healthful supply, and we shall secure the product through natural channels of distribution.

The problem of securing an abundant supply of water for domestic and other uses is one which has always been difficult for cities to solve. The Romans spent limitless money and countless lives upon their aqueducts. New York to-day is spending fabulous numbers of dollars and wasting as many lives as Rome

MUNICIPAL SUPPLY

wasted to bring the water from the Catskills uncontaminated to her faucets. Chicago has recently spent \$65,000,000 to drain her own sewage out of her drinking water, and will soon have to spend an equal sum to drain it out of the water of her neighbors. Pittsburg has spent a fortune to filter the water of the Allegheny and make it fit to drink, thereby greatly reducing her typhoid scourge; but she still pours her own filth into the Ohio for the benefit of Sewickly and Wheeling. Flowing on down to Cairo it combines with that from St. Louis and Chicago, St. Paul, and Kansas City, Nashville, and Chattanooga, and a thousand other cities, and flows on down to Southport, where New Orleans pumps it from the river bed and sends it coursing through her mains.

And it is not only the cities that pollute the streams. The gas factories fill them with water impregnated with ammonia; the paper mills pour a vile slush into them; chemical works add their waste; and there is scarcely a

THE CONSERVATION OF WATER

factory which does not discharge materials which render the water unfit for human use and impossible for fish to live in.

Three wrongs are done thereby. First, the water is rendered unpotable, forcing cities to establish very expensive storage systems often at a great distance. Second, the fish are destroyed, thereby reducing a very necessary source of food from which Illinois alone, in her prairie river, secures an income of \$1,000,000 annually. Third, and this some day to be looked upon as the greatest evil, there is wasted and lost in this way not only a lot of material from the manufactories which could be saved and re-used in the arts, but also a great amount of phosphorus, chiefly in the human waste from the sewers, which is taken from the soil in growing crops and which we have no way of replacing unless we save the sewage.

For these three reasons if for no others the day will come when every sewer will enter into a conserving plant which will extract everything of value from it and discharge only harm-

MUNICIPAL SUPPLY

less, pure water; every factory will develop the conservation of its waste and be carefully inspected to prevent stream pollution; and every river in America will flow pure and uncontaminated from its source to the sea so that any city which wishes may pump from it and use the water so drawn.

If we should turn to almost any city in America, though there are a few now which have sanitary sewage disposal plants, we should find strikingly displayed the national carelessness about this matter. We cannot find one more typical in this, nor one which shows more clearly the futility of the old-time methods of correction than Chicago. From its earliest foundation until a decade ago Chicago poured its sewage out into Lake Michigan and then pumped it back for drinking water, wasting at the same time the phosphorus in the sewage, and the lives of its citizens. When it decided on a change it reversed the current in its river and sent the sewage down to St. Louis, leaving Lake Michigan to purify itself by slow degrees.

THE CONSERVATION OF WATER

All the sewers of Chicago in the old days emptied into the Chicago river and so into the lake, or emptied directly into the lake itself.

At the head of the South Branch of the Chicago river at Bridgeport the state of Illinois owned a pumping station, through which water was lifted into the summit level of the Illinois and Michigan canal. Water it was called by courtesy. At the side of the pumping station was the outlet of a branch called "Bubbly Creek" from the gas which boiled out of it continually from decaying animal matter beneath the surface. At the other end of Bubbly Creek were the Stock Yards and Packingtown, and for years without number all the waste from the animals slaughtered in Packingtown and its vicinity went into Bubbly Creek. This creek had no natural current except when there was a heavy rain, which set it forward a little into the river. Sewers pouring into it kept up a current of perhaps a third of a mile a day. Entrails of animals, filth unspeakable, floated or sank to the bottom of the



CHICAGO SANITARY CANAL

CHICAGO SANITARY CANAL

This is a view of the Chicago Sanitary Canal before the water was admitted to it. After dumping all her sewage for scores of years into Lake Michigan and then pumping it back for drinking water, Chicago, to stop her endemic typhoid fever, dug this channel through the Divide separating her from the Mississippi Valley and turned her sewage into it. Before many years she will have to stop using this as a sewage channel, but it will remain a magnificent ship canal, a link in the great Lakes-to-the-Gulf Deep Waterway connecting Chicago with New Orleans.

MUNICIPAL SUPPLY

putrid mess, black as ink, covered with black scum, and smelling so foully that the name "Bridgeport" was hated all over Chicago as the name of the ill-smelling southwest wind. Chickens scratched in the scum on the river, and children, to go swimming in the murky semi-solid, had first to push the floating stuff away with sticks and clear a place.

This was the water which with criminal recklessness Chicago poured for a generation into the old Illinois and Michigan canal; and the horror and the foul odor of it were apparent for one hundred miles below Chicago. Farther than that, in fact, for when the Illinois river froze in the winter this foul contribution from Chicago actually killed the fish.

All the sewage, however, did not go down the back way. Much of it went out into Lake Michigan, where also emptied a great battery of sewers, and where empties to-day the whole South Chicago sewage system. Then from stations along the shore Chicago set out her intake water pipes, and drew back and used for drink-

THE CONSERVATION OF WATER

ing water the typhoid germs and other forms of disease she had recently rid herself of. This state of affairs went on for decades, while the city worked itself to a condition in which typhoid was endemic, and every paper in the city carried a line beseeching the people to "boil the water." Then Chicago cast about for some means to divert this sewage and purify her water. She created a Sanitary District, and at enormous expense cut a ship canal through the rock of the Chicago Divide to make her whole river run down the Illinois to the Mississippi. She reorganized her sewage system so as to divert most of it into the river and send it down the canal, and she secured a permit from the government and a law from the state by which she must dilute the sewage with lake water in enormous proportions. In other words, she will save her own lake water, but she will still pour everything into running water and let the cities down the valley stand the consequences.

As a ship channel Chicago's sanitary canal is a great success and will return richly to the

MUNICIPAL SUPPLY

city. As a power canal it is of the highest value. But as a sanitary project it is only a flushing channel for the lake, a temporary relief, until Chicago can begin a sewage disposal system. To waste the effluvia and sewage of 2,000,000 people, containing phosphates needed by the soil, is a crime which civilization will not long permit. But to pollute running water with it even under dilution is equally criminal; and before long Chicago will have reached the limit of dilution while her population will still increase.

Many of our principal cities are situated upon the seaboard, where the discharge of their waste does not affect running water which is to be needed again for any purpose whatever; as New York and San Francisco, Seattle and Boston. But even in these cases the continual emptying of sewage and garbage into the sea creates a condition upon the adjacent shores which in time becomes impossible; and the economic loss of the sewage and the other elements of waste is so great that it cannot be long

THE CONSERVATION OF WATER

tolerated. Total destruction of dangerous germs in sewage and the complete utilization of the fertilizing materials contained in it is an essential to which the nation will in time be aroused.

The other aspect of the question, that of obtaining pure water supplies, grows annually more complicated. It becomes necessary under our careless conditions of living for every great city to secure an entire watershed of sufficient capacity to supply its needs, and to devastate this watershed, driving people from it, so that their presence may not contaminate the supply. Massachusetts created for Boston the Metropolitan Water Commission, which secured a tract of land many miles from the city, removed farmsteads, factories and whole villages, disinfected the land upon which they had stood, scraped away the humus and fertile earth to be used elsewhere, and in the place of a lovely upland valley left a barren expanse of sand and gravel which was gradually overflowed and became the bed of an immense series of



SITE OF THE WACHUSETT RESERVOIR, NEAR CLINTON, MASSACHUSETTS

SITE OF THE WACHUSETT RESERVOIR, NEAR CLINTON, MASSACHUSETTS

Massachusetts created for Boston the Metropolitan Water Commission, which secured a tract of land about forty miles from the city, removed farmsteads, factories, and whole villages, disinfected the land upon which they had stood, scraped away the humus and fertile earth to be used elsewhere, and turned the valley into an immense series of reservoirs, held in check by the Wachusett Dam.

MUNICIPAL SUPPLY.

reservoirs, held in check by the Wachusett dam.

New York, which has long depended upon the use of the Croton river watershed, now finds that supply growing insufficient, and is spending almost uncounted millions of dollars to secure in the Catskills a great drainage shed embracing the supplies of several rivers, and to bring this supply to New York. A costly aqueduct more than one hundred miles in length, involving a steep descent down from the mountains and a tunnel more than one hundred feet deep for siphoning the water under enormous pressure under the Hudson river, are but single features of a project upon which thousands of men are involved and which when completed will give the city an abundant supply for many years, but which renders desolate and otherwise useless a great area of land.

Such isolation of land for municipal supply would not be necessary if those who dwell either in farmsteads or in cities and villages upon the watersheds were educated in proper sanitation

THE CONSERVATION OF WATER

and in the conservation of the home sewage. And they will not be so educated, and directed by the state toward such a course, until the cities themselves follow that course. A farming or municipal community living upon the watershed of a river under proper conditions should leave that stream as pure and as clean as though there were no community there. And in time that condition will obtain upon every river in America.

Meanwhile many other cities are compelled to go as far afield as New York for their water supply; and in doing so they are finding that one department of water conservation is certain to be bound up with another; and that any measure we may take to save and use water results in profits from sources we have not anticipated. Thus we may cite the example of Los Angeles. Seeking an abundant supply of water in an almost desert region Los Angeles went far afield, nearly two hundred miles away, to the snow-capped mountains, and dammed and reservoired Owen lake and river far up

MUNICIPAL SUPPLY

in the highlands. From there to the city an aqueduct, part of the way open concrete canal, part of the way tunnel, part of the way concrete flume pitching steeply down the hillside conveys the water. But when the whole project, costing \$40,000,000 was well under way someone discovered that there was enormous power developed in bringing this water down the hillside. An investigation developed that the power was more than enough to pay for the whole work; and so Los Angeles is to have an abundant water supply from clear mountain sources, and instead of having a heavy municipal debt on account of it will have cheap and abundant waterpower to sell to pay the debt and after that in perpetuity a steady income to carry on beautiful public works. The water supply beside being enough for domestic use leaves also a great deal for irrigation; and the land about the city will supply fruit and truck for its inhabitants. Three elements of Conservation are here developed together, power, irrigation and domestic supply; and like all the other

THE CONSERVATION OF WATER

instances we have examined and shall examine, they have their base upon a water farm — upon a storage basin at headwaters.

So has the plan which San Francisco is making to expend \$50,000,000 in a similar project. In the chapter on power we shall see how this city is surrounded and controlled by a great corporation which has secured all the available lakes and rivers within easy reach of the city, both for municipal supply and for electrical power. The domestic supply furnished by private interests being insufficient the city cast about for another; and the nearest available supply was that of the Tuolumne river where it flows through the Hetch-Hetchy valley in Yosemite National Park.

This beautiful valley will never have a higher function to perform than to act as a storage reservoir for the great port one hundred and fifty miles away. With a beautiful dam at its outlet, the water raised to a high and steady level, pure and uncontaminated, it will make of this mountain-girt cañon one of the most



THE WACHUSETT DAM COMPLETED, WITH THE RESERVOIR FULL

THE WACHUSETT DAM COMPLETED, WITH THE RESERVOIR FULL
The water is conducted by aqueducts and otherwise to distributing centers in the Boston district
and thence piped for the supply of the city.

MUNICIPAL SUPPLY.

beautiful places in the world and add indescribably to the attractions of that part of Yosemite.

Like Los Angeles, San Francisco — not working through a corporation or benefitting any private interest, but as a public body working for the people themselves — will establish here a water farm from which to supply its table. Enough water can be stored here to give the city a daily supply of 200,000,000 gallons, more than four times as much as it uses to-day. And this water conducted as that for Los Angeles is conducted, through aqueducts and conduits, down from the mountains, will on its way create enough waterpower to set the city free from the control of the single corporation which now owns the Central California electrical business.

Mining white coal — we find these two great cities of California going at it on their own account, as a collateral work with water farming; and what they are doing the cities to the north of them must do, and Chicago is already doing. We cannot segregate a single instance

THE CONSERVATION OF WATER

of the use of water and find the water useful for nothing else. The federal government has tried that upon the navigable rivers and has found that every step taken upon them, every task carried out, improves some other element even more than it does navigation. The states have tried it with the same result. The cities are trying it and the same thing happens. All the elements which together constitute the conservation of water and which in the end are all based upon Ezry Perkins' bottom land and the water farm the city man established there, are so closely linked up that whichever one we attempt to develop the others advance with it.

The total municipal supply of the United States to-day, not counting the half of the population which lives upon wells, is about 14,500 second feet, half the normal low water flow of the Mississippi above the Illinois. Taken a little here, a little there from many rivers, it has no appreciable effect upon most of them. The great bulk of it, used for flushing, if prop-

MUNICIPAL SUPPLY

erly treated after it returns to the sewers, will flow back into the river as pure and usable as it left them. Probably not 2,000 second feet will be permanently lost from our rivers.

The purification of sewage and the saving of the useful material in it is a matter which cities and individual factories must take up for themselves; but they must be advised and helped by public commissions. The actual purification of the rivers Uncle Sam and the States can compel. They have only to insist that within a given period all cities shall cease discharging sewage into the running streams and all factories from spilling waste into them and an economic revolution will be set on foot. In a twinkling, after the first complaints have ceased, the profitable side of the undertaking will appear, and the work will advance steadily and rapidly. As storage advances at headwaters and protective measures against erosion are undertaken the streams will become clearer, and the unhealthful low water seasons will cease. Floods, which scour pollution into

THE CONSERVATION OF WATER

U the streams, will cease. And in the end nothing is more certain than that every river will be made pure and kept undefiled, municipal supplies will be available from each of them, and the problems of the cities will be simplified in the same measure that domestic economy is increased.

CHAPTER V.

WATERPOWER, THE MINING OF THE WHITE COAL

Every mountain brook, bursting over the edge of a precipice and plunging into the bed of a ravine below; every leaping rapid, smothered in its own foam; every swift-running river, across which a dam can be placed to improve navigation, is a mine of the new fuel, white coal, eternal and inexhaustible. The mining of this new fuel has become one of the greatest industries of the day; but we are only seeing it in its infancy. For generations it will go on developing and increasing, becoming at every step more wonderful and more perfect. As we have freed the factory from the thralldom of the mill wheel by interposing the electrical generator and the copper wire, so we shall free it in time even from the tenuous wire which now links it to the river side, and drift the

THE CONSERVATION OF WATER

power to its looms and spindles by some mysterious direction through the air.

Traveling through the country to-day one comes continually upon the sign of this new industry. Tall steel poles, carrying at their summits immense insulators, supporting the slender wires which bear the high-tension electric currents, generated by water power, reach out in every direction from the central station and extend fifty, one hundred, even two hundred miles. In ten years they will reach a thousand miles, and in a generation we might, if we would, light New York with power obtained in the Sierras. They stride over hills and valleys, across farms and through villages; and wherever they go mills, factories, water-pumping stations, city lighting plants, even the farms, abandon black coal, abandon furnaces and stoves, abandon boilers and old-fashioned engines, and tap the slender wires for the new power — the White Coal of the Twentieth Century.

From Niagara into Canada and New York,

MINING OF WHITE COAL

from the numberless falls of the Coosa and the Tennessee, from the eastern fall line of the Appalachians, from the torrents of the Cascades and the Sierras and the mighty rapids of the Columbia, from the eternal discharge of Sault Ste. Marie and of the Chicago Sanitary Canal, and from thousands and doubling thousands of other waterfalls where the new "hydro-electric" stations have been installed to turn the rainfall into power, these wires reach out.

Through them with infinite speed flashes the new power of water-generated electricity. That limpid stream, which has for so many centuries plunged unhindered down the hill-side, wasting its force, now imprisoned behind a dam and led in solid column through a penstock upon a turbine — that force of position which it abandons on falling from an upper to a lower level, is now gathered into these slender wires and through them is led away to do the work of the world; while, below, the brook flows on as freely as before.

THE CONSERVATION OF WATER

What is this power, this new white fuel that we are developing from the running streams? It is the power of the water running over the wheel beside which your father played in boyhood. I have in mind such a mill now, on a hillside in East Tennessee, above the swift-flowing Doe near where it enters into the Watauga. It is a historic spot, this Happy Valley country whence Shelby and Sevier marched to the battle of King's Mountain, and it is the grandson of one of the men who marched with him who runs the mill at Valley Forge on the steep hillside above the Doe.

The Doe itself is a swift and powerful stream, and a generation ago it furnished the power which turned the enormous triphammers which pounded the iron ingots of the Tennessee mountains into bar iron for the lower river trade. But the old dams are washed away, the old mills and the forges are gone, and there remains only, far up the hillside, a millshed and a great wheel, forty feet or more in diameter — 'Lije Williams' grist mill. A hun-





'LIJE WILLIAMS' MILL

U. S. N.

MINING OF WHITE COAL

dred yards back of the mill is the little garden and the cottage where 'Lije and his wife wait for their customers, and see them come across the ford or the slender hanging bridge over the Doe, bringing the corn to be ground.

From the house to the mill runs a slender brook, to gather its waters in a "forebay" not more than ten feet across. And from this forebay runs a four inch wide flume, leading out to the top of the immense wheel. The wheel is rimmed with buckets, and when there is corn to be ground, and when the little brook has filled the forebay with water enough to run the mill for thirty minutes or an hour, 'Lije throws the corn in the hopper, and opens the tiny sluice gate. The water runs out and fills the buckets, the ancient wheel revolves, the mill stones begin to grumble, and soon out comes the grist. A handful of it from every peck — that is the miller's toll for the grinding. The Doe is too big and too intractable for 'Lije Williams to harness it. The needs of the mountaineer do not require it. But some of these days there

THE CONSERVATION OF WATER

will be erected across the Doe not one dam but a dozen at different points, each a tremendous concrete structure one hundred feet or more in height, penning up the spring flood water, and providing a head from which it will descend all through the year, steadily, night and day, spinning the electric generators and sending power through its wires out to distant lands. The peace and quiet of Happy Valley will be disturbed only when the workmen are building the dam. The old grist mill will still continue turning on the hillside. But in the valley below it the concrete dam, the tile-roofed power house without chimney or boiler, the copper wires on their tall towers striding over the mountains, the ceaseless purring of the power-makers, will stand in sharp contrast with the old times, marking the changes of the new. 'Lije Williams mined the white coal as a farmer in Illinois digs black fuel from the outcropping on his farm; but the new plant will be a modern and scientific mine.

The power that turns the old wheel on the

MINING OF WHITE COAL

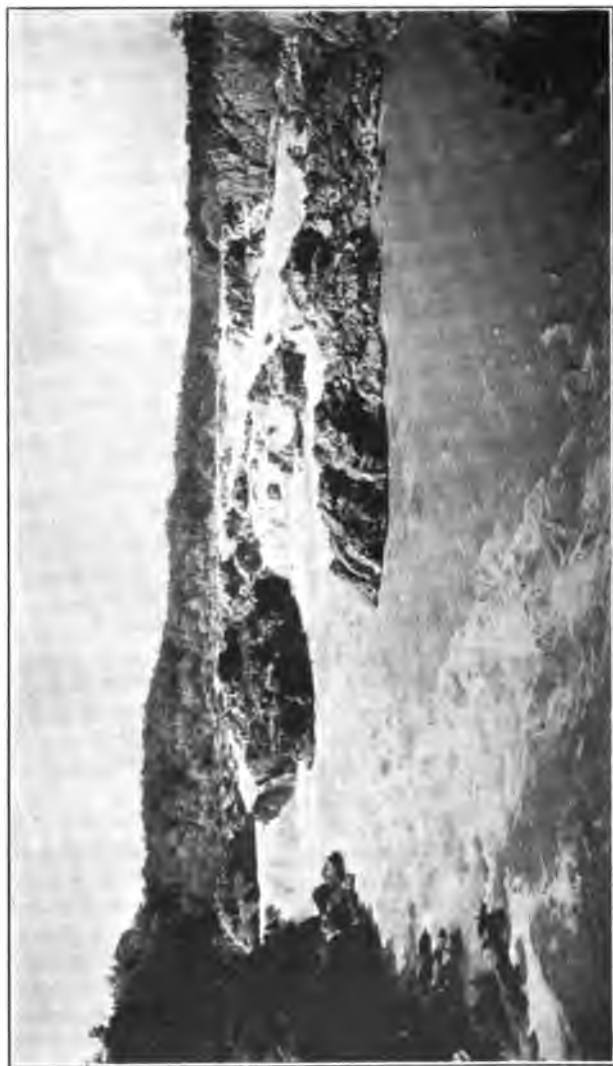
hillside is the weight of the water which fills the buckets—the force of gravity. And it is exactly the same force in the water shooting with incredible speed down the mountainside which spins the turbines and thrills the wire of the largest power plants of to-day. It is the same force which lures all rivers to the sea. Some day we shall find means to make each river turn mill wheels as it runs, even the mighty Mississippi; but to-day we can only use this where there exists by nature an abrupt change of level, like a waterfall or rapid, or where we can create such a change of level by holding the water back behind a dam. This change of level, or rather the difference between the height of the water above the dam and the height below, is called a “head” and from it we compute how much power a given quantity of water will develop.

Rivers, as we have seen, are surveyed and measured in “second feet” of running water—the amount of water in cubic feet which passes a given place each second. When we wish to

THE CONSERVATION OF WATER

develop a waterpower we must first determine how much water falls each year on the watershed above the dam and what proportion runs off through the river. Then we must discover how much of the unnecessary flood water we can store up to release in dry times, and compute the lowest flow we need expect to get. If there are at least 300 days in the year when we can be certain of a flow of 3,000 second feet that is the amount for which a plant can be profitably installed.

A horsepower is the power needed to lift 550 pounds one foot in one second. Measured in electric energy it is 746 watts; or a kilowatt, a thousand watts, is 1.34 horsepower. A cubic foot of water weighs 62.5 pounds. Therefore 8.8 cubic feet falling one foot each second are equal to a horsepower; but as machinery is not perfect and we lose something in the turbine, something in the generator, and something more in transmission, we figure that twelve second feet for every foot of fall constitute a horsepower. Then if our river has



POTOMAC GREAT FALLS. UNDEVELOPED POWER

POTOMAC GREAT FALLS. UNDEVELOPED POWER

This fall in the Potomac at Washington is a potential source of great power. It needs a dam erected below the falls to a height greater than their head, and an electric generating station below the dam, to give enough power for all the government buildings in Washington. Once the government owned an undivided half of this fall, but a political trick turned it into an undivided fourth, so that if it is ever developed for public use a very large sum will have to be paid the politicians who arranged the deal.

MINING OF WHITE COAL

3,000 second feet of flow and an efficient "head" of twelve feet it will produce continually 3,000 horsepower. But if there is a large pond above the dam for storing water, and if the power is needed only in the day time, the whole night flow of the river can be saved in the pond and 6,000 second feet run through during the day, giving 6,000 horsepower. This is the value of the old mill pond—the value of pondage, as distinct from storage. Storage carries a river from high season through low season to a high season again; pondage carries a local mill over the fluctuations of a day and night.

The little mill on the hillside over the Doe was the most primitive of all American water-wheels. Much larger and more complete establishments were set on every brook and river of New England to turn the sawmills which ate up the white pine forests; and in Wisconsin and Michigan and Minnesota the mill wheels still whirr over the tumbling water, turning logs into lumber. But there came a larger

THE CONSERVATION OF WATER

development beginning fifty or sixty years ago and extending down to our own time — the development of larger powers which were more costly and more powerful than a single factory needed. Dams were built in the Merrimac at Lowell, in the Connecticut at Holyoke and at many other places which turned all the water of the river into a head canal. This canal extended for a mile or more on a level and then spilled its water at the end into another canal 12 or 15 feet lower, which ran back parallel with the upper one and a hundred yards from it. Parallel with this was often a third fifteen feet lower yet, and at the lower end of this the water spilled back into the river.

In this development factories located between the parallel canals, and each mill drew water from the canal at its upper or front door, and after running it through the turbines shot it out into the canal at the back. As a result a dozen to two score mills were established on a single waterpower, each having its machinery operated, and no one of them having to bear

MINING OF WHITE COAL

the whole development. This cheap power thus generated gave rise to the great milling industry of New England. Paper mills, grinding rags and wood pulp into paper, cotton mills spinning and weaving cotton cloth, woolen mills, sprang up in every village which had a waterpower, and local industry leading to such big manufacturing cities as those I have named, to Lewiston, Dover, Manchester, and many more, brought prosperity to New England. This was white coal mining of a good type.

Even in this method, however, the mill must come to the mine. Power can only be transmitted mechanically a short distance and mills which needed waterpower must locate within a stone's throw of the river bank. In many instances this was practical; but there remained such falls as Shawinigan, in the wilderness of Canada, Muscle Shoals and the Suck in the Tennessee, the falls of the Coosa, and countless others in the western mountains which were not near cities or in locations where cities could be profitably developed. Often an existing city

THE CONSERVATION OF WATER

was twenty to fifty miles from a waterfall the water of which went to waste. So when the first electric dynamo was coupled to the top of a turbine shaft, and the force which dragged the water downhill was turned into an electric current a new era began. It continued developing rapidly as means were found to send the power eight or ten miles from the wheels — to distribute it to motors set in shops all over the city; to drive the street railways and to light the cities with it. Then when it could be carried one hundred miles more distant waterfalls came into use to carry city burdens; and with every additional mile this has increased until to-day St. Louis is preparing to cure much of her smoke nuisance by bringing power by wire from the falls of the Mississippi at Keokuk, Iowa, one hundred and eighty miles away.

This is done by turning out electric current at high pressure, in alternating or many-phase currents, and sending it through the wires at a tension of 50,000 volts.

As this business has grown many problems

MINING OF WHITE COAL

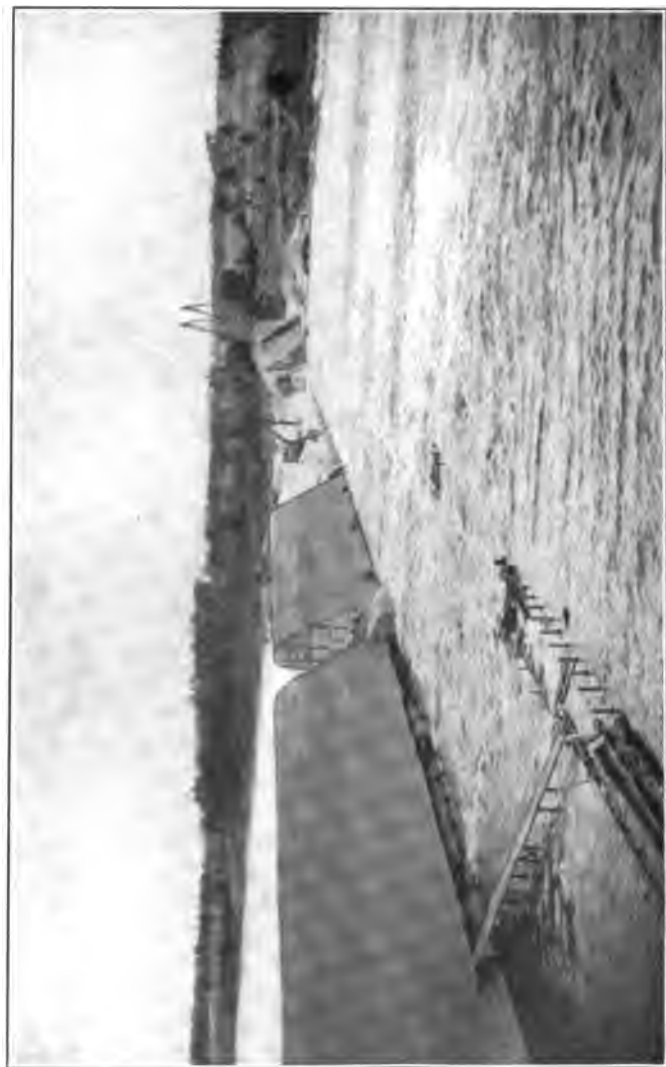
have come up and the solution of them has made the development of waterpower a question of national importance. The uses of electricity are very varied. It is needed twenty-four hours in the day to pump water in city mains. It is needed every hour of the day to operate railways and to drive many mills. Other mills need power only eight, nine or ten hours during the heart of the day. Street railways need their greatest power at irregular periods but chiefly in the so-called "rush" hours at morning and night when people are going to and from work, and at the theater hour. City lighting requires its heaviest power from six at night to one in the morning, and the demand for domestic lighting comes in the early morning and in the evening. Paper mills take power twenty-four hours, steadily, and so do nitrate and other chemical electrical works. This wide variation in demand makes it certain that a power plant which is sufficient to support the "peak" load of any business will have surplus power during the rest of the day and night

THE CONSERVATION OF WATER

— and yet the investment often requires constant earning at full capacity.

There has grown up, therefore, the very profitable practice of “linking up” plants — that is, combining in the same switchboard a large number of generating stations, which serve a wide variety of industries. Then their combined power is always at the disposal of the enterprise which happens at any given time to be calling for its “peak” or highest load, and there is no period of the day when they are required to shut down. Of course the ideal situation is never thus attained, but every station in the linking up secures some benefit.

Out of this and out of other economic conditions with which we have nothing to do here grows a tendency to combine and control waterpower development under a single head; and nearly all the great waterpower companies are already in this way loosely associated together so that they operate in harmony. As this tendency increases this association inclines to become a monopoly with very harmful possi-



A DAM UNDER CONSTRUCTION

A DAM UNDER CONSTRUCTION

This is a typical concrete structure across the Pee Dee River in North Carolina, used entirely to develop power. When the gaps are closed the water will rise behind it to its crest, and be led away at one side through a race to the turbines, to develop electric power for cotton mills.

MINING OF WHITE COAL

bilities to the public, as will be seen when we consider the industries which depend upon power. But if this combination is taken under public regulation and more and more under public control it becomes a tremendous factor for public economy and public good. Let us see how this works out.

The value of waterpower, or the cost of the electric power which it generates, depends upon the local cost of steam power. At St. Anthony's Falls waterpower, pure and simple, on the turbine wheel, is sold for \$6 a horsepower year for a twenty-four hour day; and at this rate it costs one cent to grind a barrel of flour. To generate a twenty-four hour horsepower from steam in Minneapolis costs about \$38 a year, and at this rate it costs more than six cents to grind a barrel of flour. Electric power from the power plant below the falls is therefore sold close to this, at \$35 a year. Augusta, Georgia, develops waterpower in her own canals and with her own dam, and sells it to her millers on the wheel at \$5.50 a

THE CONSERVATION OF WATER

year for an eleven hour day — a very low price. In Chicago power from coal is cheap, and ten hour electric power costs from \$15 to \$18 a year. In Spokane, Washington, the same power, more cheaply generated, sells for \$40 a year, because the equivalent fuel is so costly; and in Nevada, where coal is still higher, buyers must pay \$100 for it.

The water from which this power is generated belongs to the public and the public right to it is recognized by many of our states, by Congress and by nearly all foreign countries. In Norway the government develops power and rents it, or sells the concession on condition that the power be sold cheaply. In Switzerland no man may develop a waterpower without consent of the legislature and then he must pay a certain tax every year. France is considering a law by which waterpower franchises will not only be taxed, but the entire plant as well as the franchise reverts to the Government at the end of fifty years. In our own country Congress has control of all waterpower de-

MINING OF WHITE COAL

veloped in navigable streams, and for a generation has been giving dam privileges away for nothing. Mr. Roosevelt, however, stopped that and now a tax of varying proportions running from fifty cents to two dollars a horsepower year is put on all power taken over a dam in a navigable stream. As a general thing also the dam builder is required to build at his own expense the lock to pass vessels by the dam. This sometimes costs \$500,000. The new dam lock at Keokuk on the Mississippi will cost more than twice that. Congress has the right to amend every existing act on water-power and may increase these taxes when it sees fit to do so.

Rivers which are not navigable, however, are the property of the states and the states must regulate them and assess the taxes for the use of power. Many states have gone forward in this direction rapidly, and none farther than Wisconsin and Oregon. In Wisconsin no person may build a dam without a permit from the state forester. His privilege is only good

THE CONSERVATION OF WATER

for twenty years and he must pay a regular tax per horsepower to the state. In addition, as we have seen, he must also support the reservoir system at headwaters. The tax in Wisconsin is used to increase the forest reservation.

In Oregon the user of waterpower must have a state license for a limited period and must pay a tax ranging from fifty cents to two dollars for each theoretical horsepower — that is, as we have seen, 550 pounds of water falling one foot each second. That really amounts to a tax of about \$3.25 on every horsepower delivered by wire, which is the fairest tax yet assessed by any American state.

There are many complicating questions however, yet to solve, and these are involved with the question of water titles which we shall discuss under the head of irrigation.

It is most necessary, however, to work out some system of control over rivers which concern several states, under which they can be reservoired at the common expense of all those who benefit, and under which taxes, state and

MINING OF WHITE COAL

national, can be made equitable. Thus when we revert to the Connecticut River we find that by any comprehensive system of control New Hampshire and Vermont will do the greater part of the reservoiring while Massachusetts and Connecticut will use the greater part of the power and get practically all the navigation benefit. Some system must be found by which the work of ameliorating the river — reservoiring it and planting forests above the reservoirs, — can be done under a big bond issue; and the bonds retired by a uniform tax per horsepower on the improvement in water-power (a tax most mill owners are glad to pay if they can have floods and droughts eliminated) a smaller tax on benefits from flood protection, and a lump sum from the federal government (or a series of annual payments) representing the navigation improvement.

A corporation not-for-profit, like the Genossenschaft of Bohemia, or like the Improvement Association of Wisconsin, chartered by Congress, might secure official recognition from

THE CONSERVATION OF WATER

each state. The power of eminent domain would be conferred by Congress, the bonds guaranteed, and the states would enact laws imposing the necessary taxes in their own borders. This immense project for the Connecticut would cost from \$50,000,000 to \$60,000,000 but it would return under ordinary charges for power not less than \$15,000,000 a year and probably more than that, so that the tax assessments could be made very low.

A wiser plan would be for the four states to agree upon the work, and apportion the cost among themselves according to the benefit each would secure; then issue the bonds and contribute to the work, and themselves tax the benefits and retire the bonds.

However this is done, state control must grow stronger each year. All over the country cities are building their own power plants and selling power to their citizens. In Illinois the state is preparing to develop more than 100,000 horsepower and Chicago an additional 30,000 from running water the income from



THE BEAR TRAP DAM IN THE CHICAGO DRAINAGE CANAL

THE BEAR TRAP DAM IN THE CHICAGO DRAINAGE CANAL

Originally this was designed to be the outlet of the canal, and all the water was spilled out and wasted. Discovering that this water created a good deal of power Chicago undertook its development, and now has 30,000 electric horsepower returning to her her investment in the sanitary channel.

MINING OF WHITE COAL

which is to be used to pay for a magnificent navigable channel through the state from the Lakes to the Mississippi. When this is done it will go to pay for other state improvements.

This is the path we must follow more and more — first state taxes, and then when the cost of the works are paid back in profits, state ownership and control of the power supply. By this means this great resource upon which the life of the nation depends will remain under the people, and the income from it will relieve them from their burden of taxation. A state is like a big family. If it is improvident and gives away its property, if it makes unconditional and perpetual franchises to its power, it remains poor. Like a tenant, who owns no land of his own, it must always pay rent, and it must tax its people to pay rent. But if it follows the example of Illinois, of Chicago, of Augusta, Georgia, and acquires producing properties such as waterpowers it dwells at home, is its own landlord and receives a steadily increasing income which it can spend

THE CONSERVATION OF WATER

on beautiful schools, on public works, on good roads, on waterways, on a new sort of happier living for the public or — as Germany uses hers — to provide labor and wages to every citizen of the republic.

A fair tax upon each horsepower used is difficult to assess. It is different in different circumstances. A general average, which could be assessed in nearly every case would be \$5 a horsepower year — but it must be accompanied by a state commission providing that the selling price of the power shall not be raised to compensate for this. Such a tax levied upon the waterpower in the navigable rivers of the country (and accompanied by additional dam development to enlarge navigation) would very quickly pay back into the national treasury all we have spent on river improvement; or, in the form of interest on bonds, would pay all that we need to complete the great waterway projects on which we are embarked.

CHAPTER VI

WATERPOWER IN NATIONAL DEVELOPMENT

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Remarkable changes in the course of national development are destined to come during the next three or four decades as the result of the development of waterpower and the extension of the transmission of electric power over longer distances. With remarkable rapidity the harnessing of waterfalls will go on, and enterprises of all sorts will be able to locate where economic conditions make it desirable — generally along the navigable waterways where transportation problems are simplified. Freedom from smoke and from the necessity of crowding about railway terminals and near coal centers will release these factories so that they will seek freer surroundings and enable their people to shun the congested city factory districts. The example of transmission

THE CONSERVATION OF WATER

set by the hydro-electric development will not wait long before it spreads to the coal mines, and we shall have economical and smokeless power houses at the mines, wiring power to the cities and to distant factories, instead of sending the coal to them by rail. The development of power and navigation go hand in hand as we shall see in the chapter on navigation, and the improvement of our principal rivers and even of the smaller streams will for several decades to come create an increasing amount of power available for manufacturing purposes adjacent to the water routes.

The uses of this power, also, are being widely extended, and their influence upon national development will be striking. Fertilizers for our soils will be made out of the air by electricity; woolens and cottons will be spun and woven even more than they are now by electricity; smelting of iron, the manufacture of steel, the electrolytic separation of copper from its ores, will depend upon hydro-electric development. Railways are at the verge of electri-

NATIONAL DEVELOPMENT

fication. In addition to the simple use of electricity as power to turn the mill wheels, the so-called electro-chemical industries are growing in number every day — industries in which electricity is used for its chemical properties — and these give rise to remarkable changes in our internal economy. It will be worth our while to study some of these industries, and to study also the strategy of location which will direct the development of cities through the new power.

The waterpowers of the country are more or less grouped in certain localities, so that it is certain that in those localities industrial development will be centered — and this centering is already well advanced. New England is a region by itself; the Adirondack and Catskill region of New York another in which waterpower is abundant. From Virginia south into Georgia and around into Alabama extends the so-called "Fall Line" of the Southern Appalachians, the sudden break at which the foothills give way to the seaboard plain.

THE CONSERVATION OF WATER

Wherever rivers cross this fall line are large waterpowers, and higher up on the headwaters of the same streams are other powers.

On the Mississippi system there are great groups, some of them already to develop, others to follow more slowly. The Tennessee offers in midlength Muscle Shoals with an ultimate development of 500,000 horsepower, and on the tributaries above Muscle Shoals certainly no less amount. The Ohio, now being improved with movable dams, will in a generation give place to reservoirs and fixed dams and generate between Pittsburg and Cairo probably 2,000,000 horsepower. The upper Mississippi presents two groups; one at headwaters including the Falls of St. Anthony offers about 200,000 horsepower, and the other in the middle river includes the Rock Island rapids, the Des Moines rapids at Keokuk, and three dams lower down near St. Louis in connection with the Deep Waterway, which will have altogether a power of about 500,000 horse, centering at

NATIONAL DEVELOPMENT

St. Louis but available for other cities along the way.

The Missouri offers large development also, but the extent of it in the lower reaches cannot now be judged. But in Montana this river has the possibility of very great development part of which is already undertaken, and should in the end produce 500,000 horsepower. The White, the Arkansas, the Washita, all will produce power, and the Illinois route from Chicago will develop altogether 150,000 horsepower for use near Chicago.

The western powers group themselves chiefly in Colorado, in Washington and Oregon, and in Central California. Washington and Oregon have several groups. One of these in Washington, Idaho and western Montana consists of the powers of the headwaters of the Columbia, including the Pend d'Oreille and Flathead, Clark's Fork and the Spokane river, all this power centering in the Inland Empire region of which Spokane is the natural trading and manufacturing center. The falls of the

THE CONSERVATION OF WATER

upper Columbia itself as far down as Priest's Rapids naturally fall in this group, which has in Oregon and Southern Idaho its corresponding district in the famous Twin Falls and the various swiftwaters of Snake and Salmon rivers and the falls of John Day and Des Chutes rivers. On the west coast the tremendous rainfall and sudden declivity of the Cascades and the Olympics, reaching the sea from remarkable elevations in but a few miles, produces a steady and large power from even the smallest streams, and there results a power region of which Seattle in Washington is a natural center, and Portland in Oregon. In between these two the greatest power river of the Pacific slope, the Columbia, offers opportunity for development in connection with both irrigation and manufacturing that will support an enormous population in the picturesque valley of that river. San Francisco is the metropolis of an extensive and magnificent power system, embracing torrents which plunge down thousands of feet from the Sierras, and the

NATIONAL DEVELOPMENT

development of irrigation and of municipal supply go hand in hand with this creation of power to increase the importance and wealth of the chief Pacific port.

Although there are individual powers in other regions of large importance, like that at Rainy River, and at the Long Sault of the St. Lawrence, it is in these regions where the great groups of powers can be concentrated that the manufacturing centers of densest population and of the greatest economic importance must be centered.

In all of these districts the tendency is to link up and combine the big power developing corporations into a single concern, or at least into a working inter-relation. By this means the combined load is carried on the whole system, surplus plants can be temporarily shut down, and the various peak loads resulting from a wide variety of enterprises can be distributed over a large number of plants. More than this the association under one control of all the plants upon a single watershed enables that

THE CONSERVATION OF WATER

company to develop to the highest extent the storage on the watershed without the necessity of involving any other enterprise.

In Colorado the chief power development is controlled by the Central Colorado Power company, a big corporation which has extensive plants at Glenwood and in Gore Cañon, capable of developing about 100,000 horsepower. In Montana the powers of the Missouri river are by a gradual consolidation all brought under a single head, the United Missouri River Power Company, and this, in turn, is closely associated with other, distant power groups. But for an illustration of the completeness of control such a system acquires and the rapidity with which it grows we may cite the company which controls the power developments about San Francisco, the Pacific Gas and Electric Company. This is a company formed by the consolidation, beginning in 1905, of a large number of local electric and gas companies. In four years it had outstanding securities of a total of about \$85,000,000. It controlled practically all the

NATIONAL DEVELOPMENT

central station electric business of Central California including eight of the ten principal cities of the state. It had eleven hydro-electric stations in the Sierras, delivering power hundreds of miles to San Francisco, and generating about 100,000 horsepower. It had in addition an equal amount of waterpower in reserve, or a total of 200,000, the equivalent of 3,000,000 tons of coal a year, economically burned. This one corporation is the sole source of electric power in a region 225 by 125 miles — a total of 31,489 square miles and containing sixty per cent of the people of California. By its unit control of the watersheds it is able to reservoir extensively and owns thirty-one reservoirs with a total storage of 3,500,000,000 cubic feet — about as much as the total storage of the Wisconsin river. Fifteen hundred miles of high tension wire carry the current from the stations to the cities, and all the stations are so linked up that an accident or an overload at one is compensated by the simple throwing of a few switches at the controlling station.

THE CONSERVATION OF WATER

Such a single system, developing to the highest degree the waterpowers of a region and placing their power at the disposal of the public is of the greatest economic importance. The development and sale of power is one of those affairs in which competition is not needed but in which co-operation brings the highest success. This consolidation and co-operation, however, should be brought about either directly through public ownership and control, or through strict laws which provide for a public share in the enterprise, and a public regulation of the prices charged for power.

It is impossible to exaggerate the value to San Francisco and to Spokane or to any other central city of a big water system, of such abundant waterpower close at hand. It means the development of industry free from smoke and cinders, the possibility of building and maintaining handsome public structures, and private commercial edifices of great beauty without subjecting them to the defacement of coal smoke and soot. It means the elimination

NATIONAL DEVELOPMENT

of a great burden of cheap freight from the railroads and greater opportunity for the distribution of high class manufactures. And in the case of the railways themselves it means the doing away with steam power and the complete substitution of electric power.

This last step the railways will take before the world is aware of it. They will transfer their energies from the mining of black coal to the use of white coal. In the east the railroad which runs from New York into Connecticut operates all its trains by electricity for many miles. The New York Central is electrifying its system and other roads are preparing to follow suit. The new line of the Chicago, Milwaukee and St. Paul railway across the continent is to be electrified through the mountains by the development of waterpower — the harnessing of the rivers of the Bitter Root range. The great tunnel of the Cascades on the Great Northern railway has been electrified. In this long tunnel the smoke formerly hung so heavily that only one train an hour could be passed

THE CONSERVATION OF WATER

through. The railway company harnessed a river which plunges along by the track, and with this power equipped the tunnel with electric engines. Now the trains pass through in rapid succession in clear air, the passengers and crews no longer suffer, and the danger of a horrible catastrophe from the suffocation of the passengers on a broken-down train — always a possibility under the old system — is eliminated.

Electrification, by waterpower and by mine central station, will sweep over the nation rapidly when it has acquired a little more momentum and the further electrification of industry and the extension of new industries will go with it.

What are these industries and especially the new industries which will depend upon power? Many of them are of vital interest to the nation, and not least of these is the manufacture of nitrates for our soil. The renewal of our soil, its fertility, its ability to support life, depends primarily upon the conservation of water;



MINING WHITE COAL

MINING WHITE COAL

This is an old-fashioned waterpower development, much more modern, however, than that of 'Lije Williams'. The water taken from above the dam is conveyed through this canal from mill to mill, and from level to level, generating power at each mill as it passes, until it has descended to the level of the river below the dam. The modern plants use all the water in a single power plant and distribute electric current to the mills. Such canals had a remarkable part in national development, being responsible for such cities as Holyoke and Lowell, Massachusetts; Lewiston, Maine; and Augusta, Georgia.

NATIONAL DEVELOPMENT

partly as we shall see by the saving of sewage to purify the rivers; but more directly by the use of electric power in nitrate manufacture.

The three mineral elements which are necessary for plant growth, in any soil, are nitrogen, phosphorus, and potassium. Potassium is a common product, and when the present abundant mines are exhausted there are other ample supplies to be tapped. Phosphorus is a rarer substance but is only used in small quantities. But nitrogen is rapidly exhausted from the soil by nearly all crops, and is in constant demand for renewal. It is the largest element in most commercial fertilizers.

The supply of nitrogen comes from packing house waste, from cotton seed, and other similar vegetable materials, a comparatively limited supply, and, the largest amount, from the famous Chilean nitrate mines. These deposits of nitrate in the desert of Chile are the largest in the world, but they are being rapidly exhausted, and when they are gone, unless some other supply existed, the world would soon

THE CONSERVATION OF WATER

starve to death. There is, however, a great, inexhaustible reservoir of nitrogen — the air we breathe. Seventy-five per cent of the air is pure nitrogen.

This aërial nitrogen, however, is useless as a supply for plants, except for such species as clover and alfalfa — legumes — which, owing to the presence of certain bacteria in them, are able to “fix” air nitrogen and store it in their roots. For the world’s supply it is necessary to fix this nitrogen into some solid form which can be distributed on the soil and absorbed from it by all manner of vegetable life. Electricity offers the only solution yet known of this problem.

There are two ways of obtaining nitrogen by electricity. One of these is direct and costly, the other indirect and cheap. The direct method is nothing more nor less than by artificial lightning. Everyone has noticed after a heavy thunder storm an acrid taste in the air. That is due to the presence of nitric acid, the nitrogen having been fixed or combined

NATIONAL DEVELOPMENT

by the lightning with hydrogen and oxygen to form nitric acid. Exactly the same process is carried on to-day in Norway and in Bavaria. In big towers prepared for the purpose beside powerful waterfalls electrically harnessed, sparks like lightning are continuously discharged; and the air through which they leap is turned into nitric acid. This acid is caught and by a chemical process is turned into a dry nitrate which can be distributed over the soil. This process requires so much power that only where electricity is cheap can it be done. It works well in Norway, where the waterfalls are very high and current can be developed for about five dollars a horsepower.

The other process which is used now and probably will be extensively used in America is less direct. Everyone is familiar with the fact, discovered some years ago, that air can be liquefied. There are several factories in operation now devoted to the manufacture of liquid air for commercial purposes — turning out a steel blue liquid intensely cold, which will

THE CONSERVATION OF WATER

freeze anything in the world and which produces remarkable chemical and mechanical results.

Just as alcohol and water can be separated in a still, the alcohol passing off at a low temperature and the water at a higher, so the nitrogen and oxygen in this liquid air can be separated by distillation. By careful regulation of the temperature the pure nitrogen evaporates, leaving liquid oxygen. This pure nitrogen gas is drawn off as the basis of a nitrate fertilizer.

Many of the largest electric industries depend for their existence upon the electric furnace — a retort through which a heavy, low tension current is sent, producing an effect like an arc light within the retort, the current passing with heavy resistance through the particles of the contained substance, and heating it to a very high degree. Iron can be smelted and steel made this way. Carborundum is made this way and aluminum is removed from its ores and turned into the light and useful sub-

NATIONAL DEVELOPMENT

stance employed in arts, by the same process. A more common industry is the manufacture of calcium carbide, from which acetylene is made. Lime and coke in the proper proportions are placed in a retort, the current is turned into them melting and fusing them, and the calcium carbide — the chemical union of the two — results.

If, into this retort containing lime and coke, or containing calcium carbide previously manufactured, the pure nitrogen gas from the liquid air is introduced under pressure, it is immediately absorbed in large quantities by the hot carbide. When the furnace is cooled and opened there is found in it not the white lumps of calcium carbide which would otherwise be there, but a slaty gray powder, calcium cyanamid — “lime nitrogen” as it is commercially known — a combination of nitrogen, lime and carbon.

Spread upon the fields this substance quickly dissolves; the lime sweetens the soil, and the nitrogen is absorbed into it and from it is

THE CONSERVATION OF WATER

drawn into the roots and so into the stems and leaves of plants.

This is the hope, and as far as we know now, the sole hope of the fields and farms of America. Only by this process can the nitrogen in our soils be renewed and enriched. And only by electric power can we obtain our supply. So the cheapening and steadying of water-power, the conservation of every part of our running streams, quickly results in the conservation of our soil, the renewal of its fertility, and the making abundant and cheap of the things we must have for food.

Cyanamid of lime, the nitrogen of the air fixed with coke and lime, has many other uses beside that of fertilizing our soil. It is a cheap source of ammonia of which we need large quantities — it has only to be mixed with water to produce it. It is a necessary element of high explosives; and in addition it is the cheap and direct route to produce the cyanides which are used in extracting gold and other metals from refractory ores.

NATIONAL DEVELOPMENT

The other chemical uses of the electric current made possible by the cheapness of hydroelectric power are almost without number, and we cannot enumerate them here. The mechanical uses are as important. In Minneapolis, where sixteen million barrels of flour are ground each year, it is estimated that it costs one cent to grind a barrel of flour with waterpower, and five cents to grind a barrel by steam power. Paper mills in fabulous numbers are run either by waterpower directly, or by hydroelectric power from some distant station. Bleaching powder is made, copper is extracted from its ore and scores of other important industries carried on by these falling waters. All along the "fall line" of the Southern Appalachians cotton mills draw their power from their streams, and in every city which has this cheap power the busy machines in the workshops are turned by it. Inter-urban railways, spreading rapidly through the country, frequently have their base of power in a concrete dam, and offer their services in a new field,

THE CONSERVATION OF WATER

that of collecting and distributing freights to be carried on the river which furnishes the power.

One of the greatest necessities in our national growth is the extension of our foreign trade. In this we meet German competition most strongly. If all our raw materials and all our factories were on the seaboard the transportation cost, which is our chief handicap, would be eliminated. But as it is, we must carry either the coal and the raw materials, or else the finished product to the seaboard to place them upon ships, and this rail haul, for which high rates are charged, is a great handicap upon us.

Most of the raw materials for manufacture are found adjacent to the rivers—lumber, lime, iron, cotton, wool, corn and wheat, and all the other products so used are found close to water. In the development of waterpower these streams are made safely navigable, and therefore they offer an outlet to the sea much cheaper than rail to products made by the elec-

NATIONAL DEVELOPMENT

tric power out of the raw materials. Therefore we may expect to see our export trade advance rapidly as the Conservation movement advances. And we may expect to see develop new types of smokeless cities, founded upon public work, upon public income instead of public taxation, at the principal falls. In the middle reach of the Tennessee, near the Muscle Shoals there should be a continuous manufacturing city for forty miles along the river with a free, deep channel to New Orleans. On the Ohio there will be a score of such cities. On the Mississippi the nucleus at St. Louis will extend far up and down the stream, and the upper Illinois Valley will hold another continuous city.

The great powers of the Columbia will provide for our Oriental trade a similar situation, and the current from the Sierras will establish on San Francisco Bay a like condition.

A remarkable instance of the new cities that are made possible by the existence of the electric power from running water is offered by the new activity at the falls of Rainy Lake River

THE CONSERVATION OF WATER

at Kouchiching, Minnesota. All northern Minnesota is forest covered, and much of it is muskeg and swamp, which is being rapidly drained and turned into a rich wheat country. It is, however, very sparsely settled. Coal can only be brought there at a very heavy expense for freight, and it would at a glance appear that this could never be a manufacturing center.

The Rainy Lake, however, reservoirized by innumerable other lakes along the Canadian border, pours out to its river over a fall nearly forty feet high a continuous flow which scarcely varies at all from low water to high water and is capable at all stages of developing 35,000 electric horsepower. This is now being harnessed — and lo! a transformation!

Canadian wheat, coming down from the northwest for export, must go through Duluth or through Thunder Bay. The shortest route to either place, and the best grades, lie along Rainy Lake River, past the falls of Kouchiching. Minnesota wheat from the rich and fertile newly drained swamp lands seeks the same

NATIONAL DEVELOPMENT

route. The hills and mountains around the lake are magnificently covered with paper wood. So here by a fairy wand the power creates the city. International Falls, developed to mill flour in transit and to manufacture paper from wood on either side of the International Boundary — for the river has Canada on one side and United States on the other — becomes at once the metropolis of the new region. Drawing from both countries, manufacturing cheaply, shipping by rail to Port Arthur, Duluth or Minneapolis, with easy water connection back into Canada through its river, and with water connection to the Mississippi system certain to come, this wilderness waterfall makes possible a handsome, smokeless and prosperous city which is now rapidly developing.

Not only in factory and city, but on the farm and in the home waterpower is doing the familiar common things. Plows are drawn, wagons driven, hay stacked, grain reaped and threshed, trees felled and cleared away, all by the power of the falling water. The house and

THE CONSERVATION OF WATER

barn are lighted with the electric glow, the cows milked by an electric driven machine, the farmer's meals cooked in an electric oven, the house warmed, the water supply pumped and heated, the butter churned, — all by the handy electric current from a nearby brook, or stepped down from the slender high-tension wire which passes by the farm from a waterfall in the open country to the city fifty miles away.

There are farms in the east and farms as far west as Idaho, where everything which can be done by mechanical power is done by electricity, and methods have been devised to make this easy and simple. A brook ten feet across and six inches deep, falling eight to ten feet in crossing the farm, set up with a cheap, home-made concrete dam, forced to run out at the bottom through a simple turbine, that needs to be tended once a week — and geared to a simple generator set on the crest of the dam — that is the farmer's equipment. Once a day he strolls down to look it over — a half hour's task. The rest of the time day and night the wheel spins

NATIONAL DEVELOPMENT

on, sending its current now through the lights, now through a motor, now into the kitchen stove and again into the bathroom radiator — and, when all these are idle, storing it up for future use in the storage battery in the corner of the barn.

That is an inkling of what we are coming to — of the day when every brook and river is harnessed, when the ponds at headwaters are controlled by dams, when the floods have ended and the low water has been done away with, when the rivers have grassy banks to the water's edge and the erosion of soil has stopped — and the hard work of city and country, of farm and village home, is done by this wise servant, tamed and controlled.

CHAPTER VII

SWAMP DRAINAGE

Some years ago the state of Louisiana sold to an enterprising citizen one hundred and forty thousand acres of land for a cent an acre. The whole tract netted the state \$1,400. It was sold as swamp land, and on that account was supposed to be useless unless it were drained. The buyer held the land for several years, and then put it on the market to sell in blocks of ten acres at \$100 an acre, reserving every alternate ten acre tract for sale later at a higher price.

This land sold at the high price was still undrained, as it was the higher parts of the big tract he had bought; but every ten acres was subject to a ten per cent deduction for ditches. In other words, it was still to pay for its own drainage. The whole tract is easily worth what the enterprising citizen is trying to sell it for,

SWAMP DRAINAGE

for it is the finest alluvial silt brought down by the Mississippi, stolen from farms far up the river. It will grow oranges, figs or truck, and in vegetables will grow easily three crops a year.

The anecdote is interesting because it illustrates among other things two points clearly: one, the sudden increase in value of land which has been transferred from the public to private hands; and, second, the enormous productivity and money value of our swamp lands. All over the United States there are such lands as this, covered with water part or all of the year, but having a rich and fertile soil to bear large crops when they are drained.

Altogether these swamps have an area equal to the whole of Indiana, Ohio and Illinois, 75,000,000 acres of the finest land in America, a tract which we could not duplicate if we searched the continent and endeavored to buy from our neighbors north and south the most fertile part of their domain. The drainage of this land is a part of the Conservation of

THE CONSERVATION OF WATER

Water. It makes available a large supply which is needed in our rivers, it renders the idle land productive, and it does away with the swamp fevers which persist in undrained localities.

Water out of place is, as a matter of fact, just as bad as no water at all. Rainfall that runs quickly from a well-sloped watershed into ponds and lakes which act as reservoirs remains thenceforth at the control of man, to be released from sluice gates as it is needed in the rivers; and water which falls upon a dry land forest seeps through the soil and follows the roots, to emerge at length in a steady discharge from the little brooks and so maintain a steady flow through dry times. But water which falls in an undrained place, whether forest or meadow, stands stagnant, destroying useful vegetation, breeding pestiferous mosquitoes and other insects, and holding useless and out of cultivation all the acres on which it lies. The water which is held up year after year on this land, to evaporate



SWAMP DRAINAGE

SWAMP DRAINAGE

This picture shows the swamp before drainage. All over the United States there are such lands as this, having altogether an area equal to the whole of Indiana, Ohio, and Illinois, — 75,000,000 acres of the finest land in America.

SWAMP DRAINAGE

slowly in the dry season, is needed badly for river improvement, for both power and navigation. Drained into reservoirs and carried through proper channels, it forms an essential factor in deepening and developing our inland waterways. And the land which by this drainage would be opened to cultivation and settlement would add not less than \$10,000,000,000 to the annual possible crop value of the nation.

The swamp lands are distributed through the nation about as follows:

Florida	20,000,000	acres
Louisiana	9,500,000	"
Mississippi	6,000,000	"
Michigan	5,000,000	"
Arkansas	6,000,000	"
Minnesota	4,000,000	"
Wisconsin	3,000,000	"
Illinois	2,500,000	"
Maine	2,500,000	"
North Carolina . . .	2,500,000	"

THE CONSERVATION OF WATER

Texas	2,500,000	"
Missouri	3,500,000	"
South Carolina . . .	2,000,000	"

Alabama, New York, Virginia and California have over 1,000,000 each and nearly every state has some amount. The plan to drain these swamps, at an expense of about two dollars an acre, means the addition to the arable land of the United States of that much territory as surely as though it were gouged out of Canada or Mexico, or were pulled up by an anchor hook from the lost Atlantis.

These swamp lands are of widely different characteristics, having but one thing in common — too much water. Thus Minnesota and Louisiana, at the head and at the foot of the Mississippi, have enormous areas subject to occasional or continual inundation, but from opposite reasons. Minnesota's swamp is the headwater plateau, surrounded by a rocky rim and filled with sluggish streams which do not properly carry off the water which falls upon

SWAMP DRAINAGE

it. The drainage problem is merely to create direct channels through which the water may run; Louisiana, on the other hand, is down at the sea level and the land has not been built up high enough to drain itself. It needs diking, like the lands of Holland, to protect it from the sea, and pumping to carry off the drainage water.

The Everglades, though almost at sea level, are surrounded by a rock rim, the cutting of which will drain them. The seaboard plain of the Carolinas needs nothing but the cutting of drainage channels through an impervious sandy soil. The shore lands of New England, like those of Louisiana, need to have the sea shut out from them; along the Mississippi the problem is generally that of diking against floods and straightening the natural drainage channels.

We will take up these engineering features later, as well as the present and future value of these lands. But it is well to look first at the history of some of the largest tracts.

THE CONSERVATION OF WATER

Until 1850 all the great swamp tracts, except those included within the original Thirteen States (the Dismal Swamp, Okefenokee, the eastern Seaboard Plain, the Jersey marshes, and the tidal lands of New England), remained in the national estate. In the middle forties there sprang up in the west a great movement for the development, by leveeing, of the navigable channels of the rivers. Conventions were held in Memphis, St. Louis and Chicago, and liberal demands upon an unwilling Congress forced that body to take some action. It was not itself willing to undertake levee building along the Mississippi; but as there was then in the valley some 32,000 square miles of fine alluvial land belonging to the nation, subject to overflow and generally covered with standing water most of the year, Congress gave this land to the states, to be used or sold by them each to create a fund for its own leveeing and drainage. It named eleven states in this bill, including Minnesota and Florida.

SWAMP DRAINAGE

None of the states has ever fulfilled the obligation laid upon it by the federal government to drain the swamps out of a fund created by their sale. Florida gave most of her 20,000,000 acres away in railway grants with no return to the state. Arkansas and Louisiana sold most of theirs at prices ranging from one cent to one dollar an acre, and Missouri did little better. Minnesota parted with the greater part of hers at low prices, and it is only recently that the states have discovered that what they have left can be better developed for the people's interest if it is kept in the public hands. Undrained swamp is worth but a song, though the timber on some of it returns a fortune to those who buy and hold it. But the drained lands are worth sometimes one hundred times as much as the undrained, and by holding and draining them, as we shall see, the state gains a tremendous resource for the people at large.

The overflow region along the Mississippi below Cairo we have heretofore considered in

THE CONSERVATION OF WATER

the chapter on flood protection, because of the tremendous work done there to shut out the Mississippi by levees.

Near Cape Girardeau in southeast Missouri the Mississippi breaks through the last outspur of the Ozark Mountains and enters an alluvial valley which it has built up of the detritus borne down by its floods and stolen from the country above. The richest and most fertile elements of the soil eroded from three-fifths of North America have in unnumbered thousands of years been carried down here and filled into an old estuary until we have land extending all the way out to the jetties of the South Pass, where, geologists say, there was formerly an arm of the sea eight hundred miles long and about forty miles wide.

In this region the river crosses from Cape Girardeau to Columbus, Kentucky, and follows the eastern bluffs to Memphis. Then it crosses diagonally to Helena, Arkansas, on the west bluffs; and then back to the east at Vicksburg and down as far as Baton Rouge, the



SWAMP DRAINAGE

SWAMP DRAINAGE

This picture shows the swamp after the digging of drainage ditches. These ditches make available water which is needed in our rivers, render idle land productive, and do away with the swamp fevers which persist in undrained localities. The land opened by this drainage to cultivation and settlement at a cost of about two dollars an acre would add not less than \$10,000,000,000 to the annual possible crop value of the nation.

SWAMP DRAINAGE

last of the high ground. Below Cape Girardeau on the west, extending to Helena, and lying opposite Memphis, it leaves a region two hundred and forty miles by forty, containing nearly 8,000 square miles of rich alluvium, covered, until recently, by the finest hardwood forest on the continent. This region — called, from its drainage stream, the St. Francis Swamp — is the first of the overflow swamps of the lower Mississippi and lies partly in Missouri and partly in Arkansas.

Beginning at Memphis on the east side and extending down to Vicksburg is an almost exactly similar tract of about the same size, known from its drainage stream as the Yazoo Delta, another stretch of hard wood forest largely cleared and producing cotton second in staple only to Sea Island and in yield to nothing in the world. Below Helena, on the west, lies the White River basin, giving place to the Tensas, named also from its river; and from this southward, the alluvial overflow lands widen out to embrace the Washita and

THE CONSERVATION OF WATER

Black and Red rivers, the Atchafalaya, the bayous Teche and La Fourche on the one side, and Manchac on the other — nearly the full width of Louisiana — to merge with the Gulf Coastal Plain.

The St. Francis Swamp will serve us for a typical illustration of the character, the problems, and the treatment of this alluvial delta. Owing to the character of all such river-bed deposits this land is higher close to the Mississippi than farther back, sloping away seven feet in the first mile and then about six inches to the mile to the back river against the bluffs into which it drains. Whatever Mississippi river water comes over the banks at high water drains naturally this way, and were the drainage streams open and straight it would find an easy course down to Helena, where it comes again to the level of the Mississippi and flows into it. Drainage alone is not a difficult problem here.

The water supply, however, is complicated because the St. Francis and the L'Angeuille

SWAMP DRAINAGE

rivers bring down from the Ozarks a tremendous flood of spring water, and in addition this whole swamp has a rainfall of its own aggregating over seventy inches a year — twice the amount of rain that falls in northern Illinois.

An entire volume could be written about this region and every page could be filled with stories of adventure concerning it. More than a hundred years ago, while the Spaniards were still masters at New Orleans, Colonel George Morgan selected New Madrid as the best of the western country, and secured a grant to 12,000,000 acres of land, which he was never able to make good. New Madrid was even then the center of a wild and adventurous group. The bends of the river near at hand were the haunts of river pirates who preyed upon the keel boats of the early days. In 1811 and 1812, in a long series of earthquakes beginning in December and extending into March or April, this whole country was subject to terrific upheaval. In the streets of

THE CONSERVATION OF WATER

New Madrid gullies opened which swallowed trees and houses. Boiling water was projected in geysers. Stretches of forest were thrown prostrate. Islands in the river disappeared and new ones sprang up. Snags and logs buried perhaps for centuries came to the surface of the river; and at one time checked by these tremendous upheavals, the river was forced to flow backward on itself. Hundreds of keel boats were wrecked and many men perished. On the Tennessee side a long irregular tract of land settled very deep, carrying its trees down with it, to form the region known to-day as the Scatters of Reelfoot and Reelfoot Lake.

When the disturbance was over most of the inhabitants had fled. The federal government gave them new dry land in other localities in exchange for their abandoned land in the St. Francis. It was asserted then that a large part of the swamp itself had settled deep under water, but it is probable its overflow was caused by the choking of its natural drain-

SWAMP DRAINAGE

age channels. At any rate, there then existed and continued to exist a very considerable tract of land continually overflowed and grown over with cypress and other huge trees. Three states come together in this region — Kentucky and Tennessee on the one hand, Missouri on the other. Arkansas is but a short distance away. A little part of Kentucky, detached from its state by a bend of the river, cut off from Tennessee by the Scatters of Reelfoot, and facing, on the Missouri side, the region of the Bayou St. John and the St. Francis, offered endless refuge for lawbreakers of all sorts. This was the home of the famous Darnell-Watson feud, which cost the lives of forty men in the twenty years required to wipe out the contending families. This was the stronghold of many a famous Missouri gang of train robbers and counterfeiters, and of the notorious James Bayou gang which held up the “Belle of Memphis” steamboat on a certain occasion and compelled her to remain for a day and a night at the river bank, the pas-

THE CONSERVATION OF WATER

sengers prisoners in their rooms, while the gang drank all the liquor on board and held a dance and revel.

Densely covered with hard woods, overflowed annually, and inhabited by gangs of cutthroats, nevertheless these lands soon passed out of state control. No effort was made to create the necessary drainage fund by either Missouri or Arkansas. The lands were sold for a song. Fifty cents an acre was no uncommon price. Even as late as 1893, when the first development of levee building began, large areas of the St. Francis bottom lands could still be bought for one dollar an acre, and the timber companies were securing large amounts at very low prices.

The central hard-wood forest was at that time one of the most magnificent resources of the Mississippi Valley States. It was filled with several sorts of oaks, immense sycamores, hickories, gum trees, cottonwoods and many other varieties. Hickories which rose eighty feet from the ground before they

SWAMP DRAINAGE

branched; white oaks, which would cut eighty foot logs; sycamores ten feet in diameter, breast high from the ground, were not uncommon; and the cypress, gum and cottonwood were of equally magnificent proportions. About 1890, when the real cutting of this forest began, Memphis became the greatest hardwood market in the world.

The first step in the drainage of these swamp lands is to shut the Mississippi out from them. This is done, as we have seen in the chapter on flood protection, by the erection of great earthen walls or levees, all along the river front, sometimes adjacent to the shore, sometimes, where the banks are caving, a mile to ten miles back. These levees are built of clear earth, containing no sticks or stumps. They are six feet thick for every foot of height, with an additional eight feet representing the crown, and often in high levees an extra reënforcement on the land side. They are bound to the earth by a "muck ditch," and after settling into place and being

THE CONSERVATION OF WATER

trimmed to the proper size and evenness are covered with grass and kept clear of weeds.

Such a levee is but a makeshift protection. Year after year it may hold the flood out; and then, in March or April, a crawfish or muskrat, or some other burrowing animal may make a tiny hole through which the entire flood will follow, sweeping aside the broken earthwork as if it were paper, and overflowing a thousand or even five thousand square miles of the rich farm land. When that happens the inhabitants take to the trees, houses are filled or destroyed, fields are often ruined by sand deposits, sickness, suffering, poverty, result. Nothing but the complete revetment of the river banks and the establishment of concrete cores in the levees will shut such floods permanently out of these swamps while floods continue to exist; and only the complete reservoiring of the Mississippi, Missouri and Ohio will make the floods impossible.

Having the river shut out, it is next neces-

SWAMP DRAINAGE

sary to provide ample drainage for the rainfall and for the water seeking the Mississippi, which pours down out of the hills. This is done by straightening and widening and deepening the natural drainage channels, the rivers, and by dredging as many straight, deep, drainage ditches to supplement them as is possible. Where it can be done without lessening the drainage advantage these canals should be made of such slope and capacity as to retain water in the summer, and so to be useful for navigation, giving the swamp farmer an outlet for his crops.

Under the influence of this drainage work the Little River district in southeastern Missouri at the head of the St. Francis has already emerged from the water, and has proved wonderfully productive. Forty acres of it make a sufficient farm. More than this, the old mud roads, impassable most of the year, have disappeared, and hard stone roads, well drained and dry, have taken their place; thus cheapening transportation and making it easier for

THE CONSERVATION OF WATER

the farmer to market his crops at any time of the year.

Below this district the St. Francis is still partly undrained. The straightening of the St. Francis river is the basis upon which all plans for further work must be based, and that requires co-operation between Congress and the State. Some day this must be done. In place of the present tortuous, shallow channel a straight channel must be dug, or at least the majority of the big bends must be cut off, and the water allowed to flow with a greater slope to the Mississippi. This will improve navigation in this region, and at the same time carry off the water rapidly, and the whole Arkansas-St. Francis region will rise above the flood. Lateral canals reaching back to the Mississippi levees will supplement this work.

The soil of the St. Francis is Mississippi river alluvium. It is capable without losing fertility, if properly managed and conserved, of producing the equivalent of a bale of cotton to every acre every year. Probably it can do

SWAMP DRAINAGE

more. But if we take this bale at fifty dollars as an average estimate of its worth, the St. Francis when fully drained and in cultivation (the hardwood having been cut away) will produce each year thirty thousand dollars per square mile, or one hundred and fifty million dollars in crop values for the whole swamp. Surely a profitable addition to our national income.

The levees in front of this swamp have cost altogether about six million dollars of which the federal government has paid two million dollars for the benefit to navigation. The additional cost of drainage should not be more than ten million dollars.

This land increases rapidly in value as it is drained. Land which has sold for one dollar an acre with the timber and water on it, has often risen to twenty dollars an acre with the water partly drained, and to one hundred dollars an acre as soon as the timber and the water were both finally removed — the timber meanwhile netting fifteen to twenty dol-

THE CONSERVATION OF WATER

lars an acre. This rapid increase in value has been coincident with swift development of the resources of the swamp; and no department of activity has been more illustrative in recent years of American adaptability and American resourcefulness. Thus when the drainage of the St. Francis swamp had hardly begun, when the levee was completed for not more than forty or fifty miles along its front, a group of three men met in one of the cities on the hill side of the swamp and planned a railway which would penetrate the rich timber and make it possible to market the lumber and ties. The problem before them was to do the work without capital.

One of them had the change from \$25 he had borrowed the day before, one of them had some legal knowledge, the third was a banker who could command \$12,000 credit. On this they began business with some wooden rails and old equipment, for which they paid in freight on ties, to be delivered after the road was built. They traded this for some

SWAMP DRAINAGE

scrap iron rails and an old locomotive and car and began hauling logs from the edge of the swamp to the nearest sawmill. The swamp was not well drained then, and they had to follow the ridges, which they did under the stimulus of bonuses and grants from persons anxious to sell and ship their timber. In ten years they built seventy-five miles, to a foothold on the Mississippi, and established a profitable railroad which facilitated the whole development of the swamp.

This is the sort of profitable development which comes through those who penetrate these swamps and seize upon opportunity. Even had not the state sold its lands for nothing, this opportunity would have come. The development of the St. Francis, but slightly drained as it is, has been rapid and indicates how eagerly and rapidly settlers will flock to such regions when the land is permanently dry.

By this sort of swamp reclamation — the cutting of out-fall canals with ditching ma-

THE CONSERVATION OF WATER

chines so that the water may run off into natural channels — most of the biggest projects are being carried on. Thus by extending the long, straight drainage ditches through her muskeg and tamarack swamps, Minnesota is turning four million acres of profitless swamp at the headwaters of the Mississippi into well-drained farming land, returning her a net income for her capitalized school fund of ten dollars an acre over the cost of drainage; and incidentally adding this immense outflow to the reservoirs of the Mississippi. South Carolina, and particularly the region about Charleston, is cutting ditches through the sandy and peaty bogs which block the drainage, and is releasing the pent-up waters which for a century made that region a deadly malarial swamp. For the health of the city alone this would be a remarkable achievement; but it is being followed by the earning of rich returns from the drained land and the establishment of hard roads through the whole section, so that prosperity as well

SWAMP DRAINAGE

as better health follow this conservation development.

Louisiana has a different problem and a vast one. In the upper parts of the state levees and drainage canals like those in the St. Francis are sufficient; but the seaboard of the state is a tidal marsh, overflowed when the hurricanes sweep in on the land, productive in an amazing degree when the water is kept off from it, favored above all the rest of America by a mild climate and abundant rain. Some day, and probably she will begin within a decade, Louisiana must treat all this seaboard marsh as Holland has treated hers, erecting staunch sea dikes along her shore, to shut out the hurricanes; and carrying them far up the estuaries and bayous. Wide canals serving drainage and navigation will be cut through the meadows, with pumps for drainage when high water forces the closing of the outfall gates. New Orleans has already done this work within its limits. Levees surround it on every side and the water is lifted over

THE CONSERVATION OF WATER

them by electric pumps. As a result the malaria-breeding swamp at the back of the city, where the water formerly stood from one to six feet deep, has been dried out into good building lots and truck gardens, and the health of the city materially improved. But when the state undertakes the greater problem it must face the fact that it no longer owns the lands which are to be benefited, but has parted with them for a song with no material benefit to the greater part of its citizens.

How much the swamp lands have brought the state it is impossible now to tell. Swamp lands along river and coast have been in demand about eight years. Such lands drained and in good condition are worth \$100 to \$150 an acre. The state sold them in 1902 for twelve and a half cents an acre — just twelve and a half times as much as they had asked a few years earlier — and in 1903 raised the price to twenty-five cents.

Louisiana has parted with her heritage for a song. She has nothing left to show for it.

SWAMP DRAINAGE

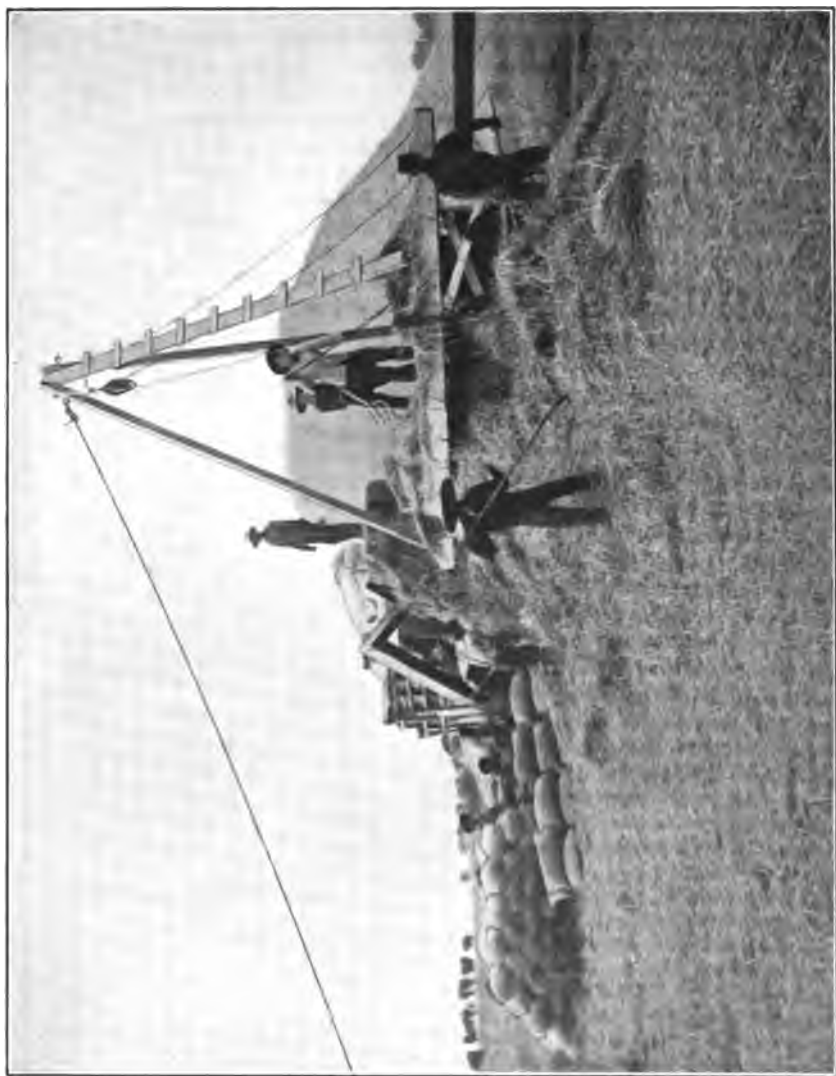
Let us look over her situation and discover if we can what would have been the result in Louisiana of maintaining this public territory and carrying it on — as we see other states carrying it on — as a public property for the good of all; let us apply, that is, the doctrine of Conservation.

Louisiana had in her original gift 9,500,000 acres of swamp and overflow land. This was the richest land in America, the choicest part of the sediment of the upper country brought down by the Mississippi, the Red and the Washita. It was finely divided, the very lightest silt; the heavier and coarser having been dropped higher upstream. In her mild climate such land produces usually three crops of truck year after year without loss of fertility. In sugar it grows steadily richer and produces usually about 3,500 pounds of dry sugar per acre. Some of it will do better than this. It produces abundantly oranges, figs and grapefruit. It is the making of a garden land beside which Holland will pale into insig-

THE CONSERVATION OF WATER

nificance, because the soil of Louisiana is richer and its climate better than that of Holland.

Suppose she had held her swamp lands and had found 8,000,000 acres of them worthy of development. At the outside such development costs eight dollars an acre. An ordinary drainage cost over a large area is two dollars an acre. A fair figure for large contracts is about five dollars an acre. That will pay for the sea dikes and the drainage canals, draw off and pump the water, and turn the now hurricane-swept coast lands into a paradise. For 8,000,000 acres it would have cost her \$40,000,000 of bonds. She would then have had public health vastly improved and a great estate to dispose of. Suppose she still retained it. Fertile, well-watered land easily becomes worth \$100 to \$250 an acre. Reclaimed swamp land in California no better than this rents for as high as \$67 an acre a year. If Louisiana had not even taken the low rent, five dollars an acre year, ordinarily charged in



HARVEST ON A DRAINED SWAMP

HARVEST ON A DRAINED SWAMP

This is a typical farming scene on the land drained and leveed in the San Joaquin Valley in California. It is a sample of the millions of acres of land now under water, idle and unsanitary, which can be made thus productive.

SWAMP DRAINAGE

the St. Francis swamp for raw land, but had asked only four dollars an acre, she would have had an annual income of \$32,000,000, of which \$7,000,000 would have amortized her debt, leaving her with \$25,000,000 each year to spend.

Now we begin to see something in this public conservation work. Louisiana has no compulsory education because she cannot afford to educate her colored children. Louisiana has child labor because she is too poor to enforce child-labor laws. Ignorance, illiteracy, bad government and child labor go hand in hand with lack of schools. Twenty-five millions a year added to her income — think what that would do for her schools!

Think of that sum, year after year, divided into things to benefit the public! Think of two million a year spent to develop great public docks and warehouses in her ports to facilitate her trade and increase the education and development of her people! Think of a million a year to put a library into every village!

THE CONSERVATION OF WATER

Think — but you cannot think to the end of the things that an income of \$25,000,000 a year, debt free, would mean to that swampy state.

More than twice the land allotted to Louisiana, 20,000,000 acres, was patented by Uncle Sam to Florida. Nearly all of this, three-fifths of the surface of the state, was given away without return, by the legislature, to induce the building of railroads.

Things went along into the 1900 decade before a governor of the state, refusing to recognize some of these transfers, plunged the whole matter into the courts and succeeded in emerging with 2,000,000 acres of the original bounty still in the state treasury.

Under the leadership of Gov. Napoleon B. Broward, Florida passed a direct taxation law which lays a tax of six cents an acre on all the land in the great drainage districts. That which includes the Everglades contains some 4,000,000 acres, of which the state owns half.

Into that wilderness of matted grass, islands

SWAMP DRAINAGE

of trees, alligators and Seminole Indians, the state started four great steel dredges, each from a different angle, at the sea edge. They tore out the soft limestone and the matted grass and soil in immense gulps, cutting canals sixty feet wide and ten feet deep into the rim of rock which held the water over the land. As they advanced the water drained off and they are well now on their way toward the shores of Lake Okechobee, the central reservoir of the Everglades, with a million acres of dry land behind them, much of it already in cultivation.

When they tap Okechobee the whole water surface will drop away ten feet or more below its former level and leave a wonderfully fertile region penetrated by ample and permanent navigable canals. This land tests so rich in nitrogen as to run in cases 2.25 per cent in that lifemaking element. One-tenth of one per cent is ample for most crops. It has been computed that every ton of this soil contains more than six dollars' worth of nitrate. Some of

THE CONSERVATION OF WATER

this drained land has produced 6,000 pounds of dry sugar to the acre, and the million acres now dry will produce in a year more than we import in two years into the United States from Cuba.

These which I have described are but a few of the swamps. Big and little they exist in every section of the country. The Reclamation Service is draining one at Klamath lake in Oregon as a part of an irrigation project. California is recovering more than a million acres from her two central rivers, the San Joaquin and the Sacramento. New England finds that the old bog holes, shunned by the farmers of a generation ago, are the richest parts of her farms to-day.

In the end, when the drainage process has been carried to its natural conclusion, obeying the law of demand for land, and the law of public health, there will be 75,000,000 acres of new farming land thrown open to our use. This land will produce in a year, if it is properly handled, more than half as much as the

SWAMP DRAINAGE

crop return we receive from our entire country to-day. If it were all in the South, under cotton conditions, it would produce with careful tillage 60,000,000 bales of cotton, five times our annual supply. If it were all in the corn country it would produce 5,000,000,000 bushels, twice our present crop. If it were divided properly it would produce all our corn crop, all our cotton crop, 250,000,000 bushels of wheat, 300,000,000 bushels of oats, and 20,000,000 tons of alfalfa and hay, — a very pretty addition to the national income, all to be had by a natural step in the Conservation of Water.

CHAPTER VIII

IRRIGATION

Everything which one does toward the Conservation of Water produces a new miracle. The harnessing of a little brook snatches the elements of life out of the air and gives them to the land to produce crops; and the same dam deepens the brook and turns it into a highway by which the farmer may cheaply market his products. The digging of a ditch transforms, almost over night, certainly in a season, a malignant, loathsome swamp into a garden, producing 6,000 pounds of dry sugar to the acre, or renting for sixty dollars an acre-year to the thrifty grower of asparagus for the canning factories. The spending of millions of dollars to provide pure drinking water for a city unexpectedly provides the people with labor-

IRRIGATION

saving power, and the public as a body with an income which turns over night into libraries, new schools, parks and help for the poor. But the miracle of them all which holds the eye, which sings in the heart of those who behold it and are of it, the miracle which means new life and hope to a great part of the nation — is the wonder work of irrigation, of the addition of water to the desert.

Out of the apparently sterile sands plants of every useful sort spring up in abundance and prosper. The continual sunshine of the desert country magnifies and prospers their growth. The fertile elements of the soil, not washed away by continual rains, but gently dissolved and held in position at the right time for absorption by the plants, add to this growth. Plant culture becomes a factory process, but the results are the results of art rather than of machinery. Orchards such as the world has never known before, wheat and alfalfa such as no other land has ever borne, potatoes and other "truck" in many times their usual abundance,

THE CONSERVATION OF WATER

reward the man who opens the gate and lets the water flow upon the land. From poverty on three hundred acres of sterile land, from labor that began before day and continued after nightfall, from heartbreaking toil and inability to care properly for his children, to easy comfort and prosperity on ten to twenty acres, to labor within the proper hours, to a rich reward in money and in self-respect, to an ability to educate his children and himself, to keep abreast of his times, to be a citizen as well as a farmer — that is the effect of the irrigation part of conservation upon the farmer of the arid lands. That is why there is a rush to the west and to independence, a starting out from city and from the farm to this new, this ancient, desert land. And that is why in the irrigation region there are springing up independent villages of farmers, intelligent, well educated, sturdy, prosperous, who travel in the winter to learn about their country, who neither buy nor sell their votes, who think strongly upon public affairs, who add, in

IRRIGATION

short, to the nation a stability and a dignity which it needs in its affairs.

And all this from the turning of a torrent into a reservoir; and the reservoired water over a desert waste.

The western part of America contains several great regions which are short of rainfall; and these are the home of irrigation. From middle Kansas west to the Rocky Mountains extends the semi-arid region, having a rainfall of ten to fifteen inches, most of it falling at the time when it is least needed for crops. In the mountains themselves there is abundant rain to water the valleys; but to the north lies Wyoming and southern Idaho — and farther east Montana and North Dakota, parched throughout the year like a desert. This southern Idaho desert reaches up around the famous Palouse wheat country into central Washington, straddles both sides of the Columbia, and includes the Yakima region and everything up to the Cascades. It takes in the land about the Umatilla reservation, and all the heart

THE CONSERVATION OF WATER

of Oregon westward almost to Hood river, and extends southward into California and Nevada, and southwestward to the marshy desert about Klamath lake. All through Nevada and Utah the desert predominates. As the progression is southward it becomes triumphant, and across southern California, Arizona and parts of New Mexico it marches in complete possession. There sand waste and desolation, peopled by the cactus and the Apache, have for the century of American invasion blocked all real progress.

Much of the desert is rock, intractable and useless. But the greater part is sand and volcanic ash, a varied, shifting soil, prey of the winds and the rare torrential rains, apparently the most worthless soil in creation. Yet it is this apparently worthless soil which yields most readily to cultivation when the water is put upon it and which creates the marvel I have described — the miracle of irrigation. There is almost no limit to the amount of land in the western country which can be improved by

IRRIGATION

irrigating ; but there is a limit to the amount of water which is available for it. Enough perhaps for 75,000,000 acres (a tract equal to all our swamps) can be provided for by close reservoiring among the mountains; and so not three states but six states, equal to Ohio, Indiana, Illinois, Iowa, Kentucky and Missouri will be added to the nation by the Conservation of water — by the drainage of the too-wet lands and the watering of the too-dry.

Irrigation is a heritage from the earliest historic times. In the ruins of Babylon are found the remains of enormous and very complete canal systems which conserved the waters of the Euphrates and the Tigris and spread them over the land of the desert. The overflow of the Nile long furnished the only fertility for Egypt, until the primitive inhabitants learned to dip the water from the river and elevate it stage by stage to the bench lands. India for 2,000 years has been engaged in irrigation, and under the English has acquired a system of irrigating and navigation

THE CONSERVATION OF WATER

canals which is one of the marvels of the world. So this form of Conservation is new only in America, where its possibilities have burst upon the nation like a meteor suddenly blazing in the sky — but not, like a meteor, as suddenly to disappear.

In this land the history of irrigation begins with the Mormons who, after their hegira, found in Utah only a few watered and fertile acres and for their own salvation began turning the water from the rivers into ditches. They found their labors doubly rewarded. From that beginning, little by little the movement spread, through private ownership, leading to struggles over water, to fierce battles for the water supply of an exhausted river, to the beginnings — as yet often crude and unsettled — of a body of “water law” making the titles to water defensible in court, and from that to the sudden systematizing and extension of irrigation under two great laws, the Reclamation act and the Carey act passed by the national Congress.

IRRIGATION

Before we take these up and examine the tremendous work that has been done under them it is necessary to have a very clear idea of just what irrigation consists of, how it is accomplished, and why there is need for public action and control of it. Irrigation originated in Utah (and has developed in many other places) in the simple process of watering lands from a river which flowed through the dry season. In many parts of the west there are rivers fed by the water from glaciers and from melting snows, or supplied by rainfall on distant mountains, which flow through parched and desolate valleys. The Snake River is such a stream in Idaho, and the magnificent Columbia in Oregon and Washington. The latter stream, clear greenish blue, with a powerful and abundant discharge, passes for hundreds of miles between irregular banks that are desolate yellow-gray desert, on which no green thing appears. No rain falls in this region in the growing season, and the water in the river below is of no use to the land above it.

THE CONSERVATION OF WATER

This situation prevailed in Utah, and the industrious Mormons, throwing little wing dams or complete cross dams out into the bed of each river, checked for a moment the flow of water. Then from the end of this they led a ditch dropping with less slope than the river, and following the contour of the bank lands, until it was high enough above the river bed to be led back upon the meadow or field and divided among smaller ditches which distributed it over all the adjacent land. When the crop upon this land needed watering the landowner simply opened his head gate — the gate at the head of his canal — and allowed the water to flow in.

This is irrigation in its simplest form. It is available at small expense only where the lands to be watered lie along the side of the stream, and are comparatively level. But even this system soon developed trouble. First one, then a dozen, then a hundred farmers settled along the stream, erected their dams, and established their canals. The little river dwindled away under the increasing demand and at last, some

IRRIGATION

summer day, when the first comer opened his head-gate to water his fields, he found the stream bed dry, settlers above having taken all the water, and his crops perished for lack of it.

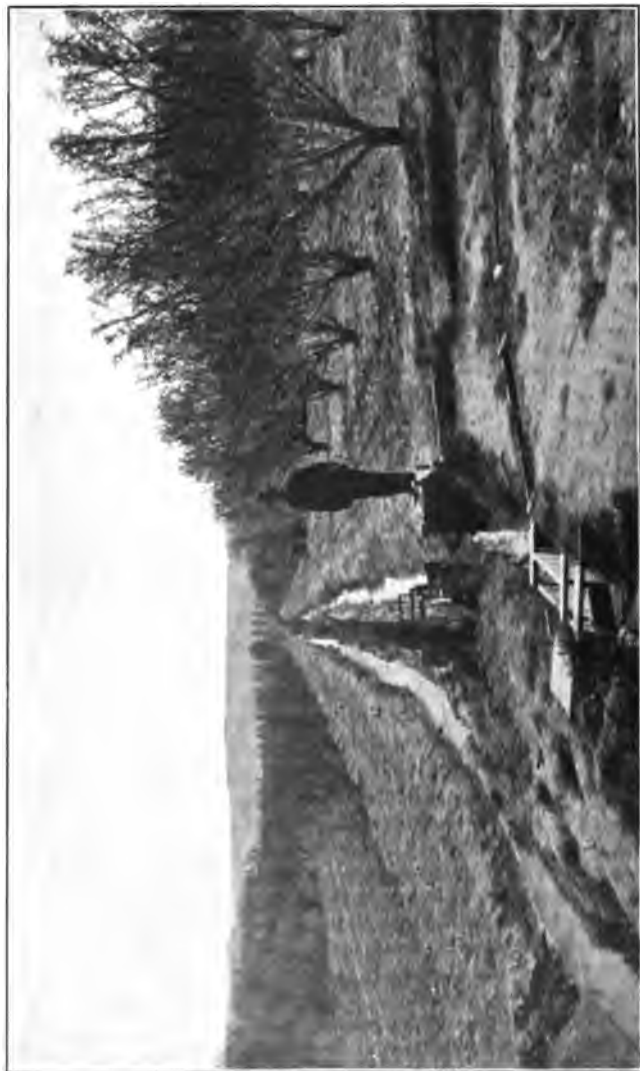
This showed at once the need of some system of distributing water, and on some rivers of Utah the farmers measured the water and divided it up among themselves on a time schedule. Thus Mr. Smith would use it from three o'clock Monday afternoon until five o'clock on Tuesday, when he would close his gate and allow the water to flow on down to Mr. Jones, below, who opened his gate by schedule at that time and took the water for twenty-four hours. This gave every one an even chance but it did not solve the problem nor greatly lessen the troubles; for more settlers still came. So there grew up the doctrine of "water rights" still one of the most complicated things about power and irrigation development in the west and much needing comprehensive settlement.

This new doctrine provided that the first appropriator of water on a river — that is the first

THE CONSERVATION OF WATER

man who located and irrigated his land — had a right thenceforth to as much water as the land he irrigated needed, or as much as he claimed and used at the time of location. He had a prior right over anyone who came after him, even though they settled higher upstream. This was undoubtedly right, for otherwise a settler having come and developed his land might be reduced to starvation by a later comer establishing above him. Step by step the prior rights on rivers were established, and as there came to be a shortage of water a settler high up on a river must often see the water flowing by his fields, water to which he had no legal right — while his own fields were drying up. Moved by the common impulses of humanity and by the suffering of his wife and children this settler would often seize and use the water despite the right of the man lower down, and many terrible battles have ensued throughout the west over the right to a running stream.

As irrigation developed the manner of using the water became more complicated. Large



IRRIGATION DITCHES IN AN ORCHARD

IRRIGATION DITCHES IN AN ORCHARD

This picture shows the manner in which water is applied to the desert to make it blossom. Two or three times in the growing season, more often if necessary, the gates at the head of these little ditches are opened, and the water admitted. It flows gently along for several hours until the ground about the roots of the trees is thoroughly saturated. Then the gates are shut, the ditches grow dry, and the surface of the ground is carefully harrowed to prevent evaporation.

IRRIGATION

corporations secured entire water rights to rivers, and installed costly canals sometimes irrigating thousands of acres, carrying the water scores of miles and dividing it according to a fixed schedule so that every settler got his share; and this tended to simplify and make more reliable the whole irrigation process. Water rights, the right to draw a definite amount of water for irrigation to a given piece of land began to be recorded and sold. A buyer of land must pay as close attention to his water title as to his land title. And so by a gradual process the legal and technical side of the business of irrigation involved a semi-legal, semi-customary ritual which governed the industry.

In this development of irrigation farmers had much to learn. Some of the desert lands were underlaid with porous subsoil which allowed all unnecessary water to drain off. Others were underlaid with impervious hardpan or rock. In the early days — and it is true yet — farmers ignorant of the small need

THE CONSERVATION OF WATER

of their land allowed a great deal too much water to flow over it, and this either settled down upon the hardpan or flowed along through the porous subsoil until it found hardpan and a resting place under some neighbor's farm lower down. Standing water under the land dissolved the alkali from the soil, and as the water increased year after year it came steadily nearer the surface until evaporation began to accumulate alkali at the surface and poison destroy the land.

In Utah alone more than a hundred thousand acres of formerly valuable irrigated farm land are now brackish alkali swamps, filled with water from the too-abundant irrigation above them; and it is only within a decade that the problem of drainage in connection with irrigation has been solved. All irrigated land should be carefully drained by tile or otherwise, and a provision made for running the drained water back into an irrigation ditch or a river at a lower level. Then the water passes off naturally without dissolving the alkali, and is

IRRIGATION

useful lower down. The lands which are ruined now can be reclaimed again by first putting in the drainage system, and then by flooding them heavily through one or two seasons and washing the alkali back deep into the soil or out through the drainage system. Irrigation and drainage must go hand in hand for the health and best use of the land.

How much water is essential for irrigation? That question is one on which many farmers and even engineers widely differ. At a state examination before the legislature of Montana not long ago farmers from the eastern part of the state placed the necessary amount all the way from six inches to twenty feet per year — that is, the amount which if it stood all at once on the land would be of that depth.

As a matter of fact the amount of rainfall during the crop season in Illinois is seldom more than twenty inches, and anything more than that is disastrous. That rainfall is not controlled, comes often at the wrong time, and

THE CONSERVATION OF WATER

does not result in as much benefit as twelve inches of rain properly applied. A foot of water used with discretion and at the right time is ordinarily enough for any crop. Two feet is far too much. A guarantee of twelve to eighteen inches with an assurance that one cannot get too much for the land is a safe provision for the wise conduct of an irrigated farm.

Rainfall is as irregular in the irrigation country as in the east, and the streams which supply the irrigated lands in summer are often roaring torrents in the winter and spring. It was from the very earliest times evident that if the flood waters could be retained and released in dry seasons the area irrigated could be increased and the business made safer. Capital, however, did not risk itself in desert enterprises, and up to 1895 there was very slow progress made in developing anything like system and reservoiring on any of the western rivers. In that year, however, Senator Carey, of Wyoming, who had from boyhood been a be-

IRRIGATION

liever in the future of the desert, fought through Congress against heavy opposition the first official recognition ever given to irrigation by the government, and paved the way for the great development of the past decade. This, the so-called "Carey Act" was merely a rider on the agricultural appropriation bill, providing that in the arid and semi-arid states of the west one million acres of desert land should be given by the government to each state, the state to make the selections, provided that within ten years the state should cause twenty acres out of every legal subdivision of forty acres to be irrigated and improved. It was provided that the land must be sold to the settler practically for nothing — fifty cents or one dollar an acre — and that no settler could have more than one hundred and sixty acres.

A year later a vital and lifegiving amendment was also passed at the instigation of Senator Carey providing that large tracts of desert lands, including the irrigation improvement works, canals and water rights, might be

THE CONSERVATION OF WATER

mortgaged to support bond issues to carry out the projects; and that as fast as each farmer completed his payments on forty acres that forty acres was absolutely freed from the mortgage and held no farther liability. That is, the failure of half the farmers to meet payments kept their land liable for the money, but could not hamper or throw a burden or cloud on the land of the rest who had paid their dues promptly.

Under this fair law irrigation by big corporations has gone forward with tremendous strides. Idaho especially has worked under it, but millions of acres in other states have been turned into gardens. Under this act a big corporation having been assigned a tract of one hundred thousand or two hundred thousand acres by the state secures the right to enough water to irrigate it, either by "filing" on the stream in its natural condition, or by creating reservoirs enough to add to an already appropriated stream enough low water flow to compensate for what they take out. Then they

IRRIGATION

issue bonds and on the money so raised erect the necessary dams and gates and canals, employ ditch-riders to run the system, and sell the water rights outright to the settlers. Each settler pays the state a small sum for his land, and pays the water company whatever it is entitled to for the water, usually about fifty dollars an acre for the perpetual ownership of the water interest, spread over ten years or more for payment. This payment transfers the dam and gates and ditches — the entire equipment with all its appurtenances and titles — to the farmers themselves who then form an association which conducts their affairs. A water charge running from fifty cents to two dollars an acre each year is paid in to this association and that is enough to keep up the ditches, employ riders, renew and repair construction work, and keep the system in working order practically in perpetuity.

This is a very practical, safe and efficient method of working out large irrigation schemes. It has been found so safe and secure

THE CONSERVATION OF WATER

that large private irrigation companies have taken up the same work in other ways, securing large tracts of land, putting in expensive and permanent canals and works, and selling the land and the water rights to the farmers at often an excessive profit — sometimes charging as high as two hundred and fifty dollars an acre for the land, or even one thousand dollars an acre for land on which an orchard has been planted.

But all this provides only for the schemes which interest private capital. There was needed some other power which, regardless of the preliminary expense, could take charge of entire rivers, reservoir them, create enormous storage, develop the power, put the water on the land, and sell on easy terms to the homesteaders, projects so complicated and expensive that the Carey Act promoters were not interested in them.

This gave rise to the national Reclamation Act, passed in June, 1902, which provides that in all the western states the money received

IRRIGATION

from the sale of public lands, less the expenses and five per cent for education, shall be set aside to create a fund for the reclamation of arid lands. A department called the Reclamation Service was created under the Interior Department and was put and continued under the charge of Frederick H. Newell, an able and inspired engineer. Under this act the Secretary of the Interior may withdraw from entry the land belonging to the government susceptible of irrigation, and turn it over to the Reclamation Service to be watered. This department then creates the necessary reservoirs, clears and establishes the titles, constructs the canals and ditches, and throws the tract open to homestead entry. This act is very faulty and only the kindly interpretation given it by Director Newell has made it possible of execution. Thus by the homestead act each farmer is compelled to build his home and live on the tract as soon as the project is begun, in order to "prove up" on his land. As it may be five to seven years before the dam is built, the ditches

THE CONSERVATION OF WATER

constructed, and the water brought, there is in the meanwhile absolutely no way for the farmer to support himself on the land and raise any crop or even to secure domestic water.

In spite of this, however, the government projects have been made popular, and immense works of tremendous strength and permanency have been developed for them. Some of these projects are colossal in their daring, their engineering audacity and their value to the nation. It is worth while at this point examining some of them to see what magnitude these works attain, what a great thing this irrigation marvel has become in the short years it has been under way.

One of the government projects which has attracted the most attention because of its astounding audacity is that of Salt River in southern Arizona, made famous first by the construction of the Roosevelt Dam. Salt River is a branch of the Gila, which in turn flows into the Colorado. It comes out of the wonderful mountains of the old Apache stronghold



THE ROOSEVELT DAM

THE ROOSEVELT DAM

This immense dam, one of the largest in the world, more than 280 feet in height, is the creator of a huge water farm. The desert land back of it, overflowed to that depth, holds back from the early floods 60,000,000,000 cubic feet of water which is released at the foot of the dam for irrigation, generating tremendous power as it escapes. The power is used to light the farmer's houses, to do the farm work, and to supply the city of Phoenix, sixty miles away.

The water released irrigates 200,000 acres. Beneath the flood back of the dam a city, built for the dambuilders, is entirely submerged. Sixty miles of road, forty of it through the mountains, were built to make this dam site accessible to the teams which carried in supplies, and a giant cement mill was built to make on the spot the cement to bind the dam together.

IRRIGATION

through which General Crook so long pursued Geronimo and his bloodthirsty warriors. It is the old land of the Cliff Dwellers, the land of sandstone and limestone cliffs, of weird and gigantic cactus, of thirst and death for the traveler — the desert land of Arizona. In the midst of it, in a great plain lies Phoenix, a beautiful city watered from Salt River; and the Reclamation project was to store and make useful the flood waters of this river for the purpose of watering the great plain and making about Phoenix a garden as beautiful as the city itself.

For this purpose the engineers went above Phoenix into the mountains to the wonderful gorge of Salt River, sprinkling the way with wells which tapped the abundant underground waters of the desert. Up through the cañon and over the spurs of the mountain they blasted out of the rock a magnificent roadway, broad and gentle, forty miles in length, over which the machinery might be teamed. In the valley itself above the dam-site they built the city of Roosevelt, destined to be overflowed when the

THE CONSERVATION OF WATER

dam was built, but meanwhile substantial, prosperous, with schools, churches and theaters, a real city for a day. They built a cement plant to make the two hundred and fifty thousand barrels of cement needed for the dam; and built a dam for waterpower above the big dam-site; carried the water for sixteen miles, plunged it through a tunnel in the mountain down a fall of two hundred and twenty feet to the turbines and developed a power of four thousand four hundred horse to light the works, to run the many machine plants and the cement mills and to do the multiple tasks connected with the building of the dam. Then in the gorge they erected the immense storage dam — a fifth of a mile along its crest and with a twenty-foot roadway on top of it, even with the top of a twenty-two-story office building had one been erected beside it. Two hundred and eighty-four feet high, arched upstream against the current, the Roosevelt dam when it was begun was the greatest in the world; and its whole purpose was to carry out the Roosevelt policy

IRRIGATION

of Conservation, by holding back the waste from Salt River to turn the desert into a productive land.

Apache Indians, children of the old warriors of Geronimo, descendants of those who drove the Cliff Dwellers from the land, labored on the road and on the dam. Some of them advanced to be foremen and inspectors, and the amazing spectacle was presented of these red men, under the direction of white engineers, conveying water for waterpower through a tunnel in the mountain constructed before the dawn of our history by the Cliff Dwellers themselves with their axes of stone.

But a dam is not the whole of an irrigation project. There must be a great canal from the dam down to the point of diversion; and numerous gates and canals for separating the water into divisions and distributing it at different levels and over broad region—for there are two hundred thousand acres under this dam.

In the desert water is lost rapidly from two

THE CONSERVATION OF WATER

causes — evaporation and seepage. It must be kept from seeping into the ground and from wasting into the air. So enclosed concrete conduits built of semiround forms of concrete — piping, really — are laid in the ditches, and the water flows through these, protected against loss, to the point where it is turned into the farmer's open ditch.

The town of Roosevelt, once numbering two thousand inhabitants, has disappeared now. Instead there lies a magnificent mountain lake, storing an immense volume of water and held back by the dam, the largest artificial lake in the world. At the foot of the dam the water escaping into the irrigation channel develops under this enormous pressure twenty-six thousand electric horsepower, and much of this is wired to Phoenix, and distributed in town and country to light the houses of the farmers and to do the work of the farms. But part of it is wired to the Sacaton Indian reservation in an act of justice seldom performed by our government. There the Pima Indians who for-



APACHES WORKING ON AN IRRIGATION PROJECT

APACHES WORKING ON AN IRRIGATION PROJECT

Years ago the Apache Indians lived beside Salt River and irrigated their gardens from it. Then white men drove them back into the barren and unwatered desert. In this picture are seen Apache Indians working on the Salt River Irrigation project, from which the government is to pump water back to the land they now occupy, undoing the wrong the early settlers did them.

IRRIGATION

merly owned large water rights have been for years carrying on a miserable existence in land from which white men had filched their water. Now the government has dug deep wells to the underground supply for them; and power created by the running water at the Roosevelt dam, carried through a slender wire, will pump this underground water to the surface and with it irrigate the lands of the civilized Indians. Thus we see water by conservation doing a treble duty — irrigating the land at Phoenix, furnishing power for city lighting, and pumping up other water to irrigate the Indian lands.

Pumping, as it is practiced to supply the needs of these Indians is not a new feature of irrigation. Even in the most primitive countries waterwheels of some sort are in use to lift water from a low to a higher level. Along the Columbia River in the most barren and desolate part of its valley one sees great waterwheels, often forty feet in diameter, set out from the bank so that the water striking their

THE CONSERVATION OF WATER

lower blades continually revolves them. Buckets attached to the side of the wheel are filled as they pass through the water, and at the top of the revolution pour the water out into a trough from which it runs to a canal. This is but a slight elevation — thirty feet or so above the river; but by conducting the water in a flume for a mile or more down the bank at a less slope than that of the river, it is brought high enough to flow over the bench lands and irrigate them. Fruit orchards, alfalfa fields and truck gardens as well as wheat fields appear as unexpected green spots in the midst of the sand and ash of the desert.

In many places, one or two of which we shall describe, the Reclamation Service and to some extent private corporations are using water-power to pump water up to high bench lands; but the most remarkable pumping development, especially as it is a far advance in Conservation, is that in the irrigation projects of the Reclamation Service along the upper Missouri river. Coming down out of Montana after its union

IRRIGATION

with the Milk and the Yellowstone Rivers the Missouri flows through a desolate region of buttes and "bad lands" where it acquires a heavy burden of silt, but does little good to the neighboring country. It is lined by bench lands on several levels and back of them high table lands, some of which can be irrigated by water brought from a long distance by canals. But for the most part the best lands are low down, near the river, and in small parcels, of two or three square miles in extent so that extensive damming and canal construction cannot be made to pay.

All of these hills of the Missouri for several hundred miles are underlaid with lignite coal, a soft brown fuel of less heat value than bituminous. This lignite crops out everywhere, sometimes in veins forty feet thick; and the greater part of it is held in reserve by the government. Experiments have shown that while it is difficult to use under a boiler, it can be consumed in a gas-producer — a modern machine for securing the largest power value

THE CONSERVATION OF WATER

from coal—and the gas from this producer can either be used in an internal combustion engine, or can be burned under a steamboiler with great economy to produce steam.

Consequently the government has decided to use this lignite coal to make the Missouri table lands productive. Mines have been opened at a central point near Williston, North Dakota, and a track built from the mine entrance to a power plant a little lower down so that the coal from the mine descends by gravity to the power house. The gas-producer is the most economical form known of burning coal, and takes the “mine run” as it comes, without the loss of slack or screenings. The largest efficiency is thus obtained, and the conservation of the fuel is put forward as an illustration of the possibilities of the day when instead of transporting fuel by rail we will turn it all into power at the mines.

The power house at the mouth of the mine produces electric current. This in turn is

IRRIGATION

carried by wire to half a dozen irrigating projects up and down the Missouri, all within one hundred miles of Williston. At each project there are several irrigating canals at various levels, the highest one hundred feet above the river. In the river floats a pumping barge, carrying electric motors and pumps which draw water from the river and deliver it in a storage basin on the lowest level. There are other motors and pumps which lift the water to the several levels above, just enough to each level to water the lands under that canal.

This project has created along the Missouri homes for several thousand families; and the work will be rapidly extended. It is of remarkable benefit. The wheat and alfalfa produced on these lands are beside a navigable river and can be readily carried to market. The seeding of the land and the cultivation under the ditches lessens the erosion and tends to improve the river. Planting trees along the irrigation canals and around the farms will further increase this tendency, and a beginning will be made toward

THE CONSERVATION OF WATER

the transformation of North Dakota and eastern Montana into a garden.

Nothing could be more desolate than this region to-day. It has long been notorious under the name of the Bad Lands. It is cut by intricate coulées — water-courses torn out by torrential rains and dry and terrible during the most of the year. These coulées slope steeply so that large reservoirs can be created only in a few places; but by the damming first of the most favorable and then of the less favorable sites, by the planting of trees along the edges of the reservoirs so created, and the use of the water for irrigation by pumping after the manner we have just described, a great change can be wrought. The increased evaporation surface during the summer will cool and modify the summer climate; the increased humidity will cause an increase of precipitation; the green fields and the forests will check the dust storms and the loss of soil, and thus facilitate the clarifying of the Missouri. This little beginning at Williston will lead the way to re-

IRRIGATION

markable achievements which will open up a large territory to settlement.

Farther west and across the mountains from the Missouri, on the watershed of the Columbia, we find another water-pumping project equally remarkable and worth our study. This is on the Flathead, or Pend d'Oreille river, just below Flathead Lake, on the Indian reservation of that name recently opened to settlement. Flathead Lake is one of the most beautiful lakes and one of the finest reservoir sites in America. Fed by Flathead and many other rivers which flow down from Lake McDonald and from the feet of the glaciers in Glacier Park, along the continental divide, it is filled with clear green-blue water, cold and very deep. The lake fluctuates very little. Along its eastern shore is a considerable area of bench land backed by the Mission Range. North of it and on the western shore are fruit lands of great value. And at the south, rising two hundred feet or more above the lake and then descending gently toward the Clarke's Fork, many miles

THE CONSERVATION OF WATER

away, is a grassy upland, an ideal farming land for grain or, with abundant water, for fruit. Through this upland the river finds its way, the outlet of the lake, through a narrow and extremely beautiful gorge, several hundred feet deep, in which it falls over rapids and precipices, green and white as it tumbles, roaring its way down to the open and gentle river below.

In this gorge the Reclamation Service is erecting a dam, to hold back the water and develop power. Later another dam farther upstream, close to the lake, will raise the level of that body and add two million acre feet to its storage capacity. But the lower dam will produce thirty thousand to fifty thousand electric horsepower, some of which will be sold and the rest used for irrigation.

On the summit of the uplands is a great basin in the prairie; and this will be transformed into a storage basin. Into this the surplus water of the river will be pumped to irrigate some two hundred thousand acres of the land below



A SAGEBRUSH DESERT

A SAGEBRUSH DESERT

All over the West are immense tracts of desert covered with sagebrush and with greasewood. The desert of Central Washington and Oregon, in which this picture was taken, is a sagebrush area, and these century-old bushes show by their size that the ground is extremely fertile, though dry. The application of water to this land will make it return six hundred bushels of potatoes to the acre.

IRRIGATION

it and turn the occasional wheat crops into regular and abundant grain, alfalfa or fruit crops. This is no desert even now, but it has occasional years of drought and too little rain for many crops. The irrigation project will give certainty to it and greater abundance, and the power will give comfort and convenience to the farmers in their homes.

This project is on the headwaters of the Columbia. When this lake is turned into a reservoir and the other great lakes of the Columbia system are similarly treated, millions of acres of the great desert which borders the stream in Washington and Oregon will be similarly treated. A beginning of this work will be made at the Umatilla project where the river of that name flows into the Columbia. A hundred miles away, on the Des Chutes River, a tremendous dam will be erected to develop power. This power will be wired to Umatilla and when the water of that small river has been exhausted the surplus of the Columbia will be pumped up on the land.

THE CONSERVATION OF WATER

Through the whole extent of the desert this combined use of power and irrigation will be extended; enough water being reserved for power to furnish what is needed, the rest being turned back upon the land. Instead of the dry, wearisome land will be a rich farming land, and a population which will produce more from each acre than is produced on any similar tract in the world.

The Umatilla project will be an example of the power from one river being used to pump the water of another; but the Reclamation engineers have gone far beyond that in their work. They have actually used one river to irrigate the valley of another, and to do so have accomplished heroic feats and astounding engineering achievements. Two such projects which have attained national fame are the Truckee-Carson, and the Gunnison-Uncompaghre projects, the one in Nevada, the other in southwestern Colorado.

The Truckee-Carson project is remarkable chiefly for the extent of the work and the union

IRRIGATION

of two rivers. The Truckee and the Carson come down from the eastern slope of the Sierras to lose themselves in the Carson sink, the western side of the famous "Forty-mile Desert" where so many of the gold seekers of the early days lost their lives. With the exception of Death Valley this is the driest spot on the continent. A dam thirty feet high has been erected in the Truckee river to divert its water into a cement lined canal thirty-one miles long. Through this it runs into the Carson River. The two rivers are thus gathered into a great basin from which in turn their conserved waters are divided into irrigation canals over the old desert land. Reno, Virginia City and Carson City and other famous towns are in the immediate vicinity.

The Gunnison-Uncompaghre project is far more remarkable, and has attained celebrity for the amazing feats of the engineers of the Reclamation Service. These two rivers flow side by side through southwestern Colorado, the Gunnison with an abundant flow of water from

THE CONSERVATION OF WATER

eternal snows, but flowing through a rocky cañon in which the water is absolutely useless for irrigation; the Uncompaghre flowing through a broad valley and having more than one hundred thousand acres of irrigable land but not enough water for it. Ten miles of mountains, two thousand feet high, separated the two rivers. In the face of apparently impassable obstacles the engineers determined to link these two rivers and compel the wasted Gunnison to water the desert of the Uncompaghre and to create upon it homes for fifty thousand persons.

Even the preliminary work was accomplished only at the risk of life and at the cost of remarkable hardship. The Black Cañon of the Gunnison was two thousand feet deep, and at the foot of it the river flowed or rather tumbled down repeated falls, over hidden rocks, between walls so precipitous that there were apparently no places on which the engineers could obtain a foothold for miles at a time.

IRRIGATION

Into this apparently certain death plunged two young engineers of the Reclamation Service, on inflated mattresses, determined to explore the gorge and determine whether the waters could be dammed and diverted through a tunnel to the Uncompaghre. Their sufferings and their narrow escapes on the trip make a story too long to relate here yet without duplication in the history of American exploring. At one time it was necessary for them successively to plunge into the river from a temporary resting place in the heart of the gorge, and allow a flood to sweep them, helpless, over the brow of a waterfall the foot of which was hidden from them and might, and probably would, be a mass of rocks on which they would be dashed to death. Nevertheless they had no alternative; and having made the leap fortunately were plunged into a deep pool and escaped alive.

Out of this trip and the information it produced the plans for the diversion of the Gunnison were completed. Even then the task was

THE CONSERVATION OF WATER

terrific in its hardships and handicaps. Many times men were lowered over the cañon walls by ropes, hundreds of feet, before a foothold was obtained and a road begun. Then a road sixteen miles long, often twenty-three per cent grade, had to be blasted out of the side of the cañon to obtain a route to the mouth of the tunnel down which machinery could be carried. A power plant had to be built in the Gunnison at heavy cost in hardship and labor, and when this was all done a tunnel must be driven through the mountain, six miles long, and ten and five-tenths by twelve feet in section. Hidden water and obstacles of many kinds interfered with progress, but the engineers solved the troubles as they arose; and at last, in the summer of 1909, President Taft, on his first trip to the west after his election to the Presidency, pressed the button which opened the gates and the Gunnison river flowed across into the valley of the Uncompaghre.

One hundred and forty thousand acres of fine land, which had never appeared to have a

IRRIGATION

a water supply, which lay under the burning sun beside a feeble and exhausted river, suddenly became available for homes, and people flocked to it in great numbers. The canals, lined with concrete, had been created while the tunnel was being bored; and in 1910 the desert of the Uncompaghre began to blossom under the efficient labor of the long-idle Gunnison.

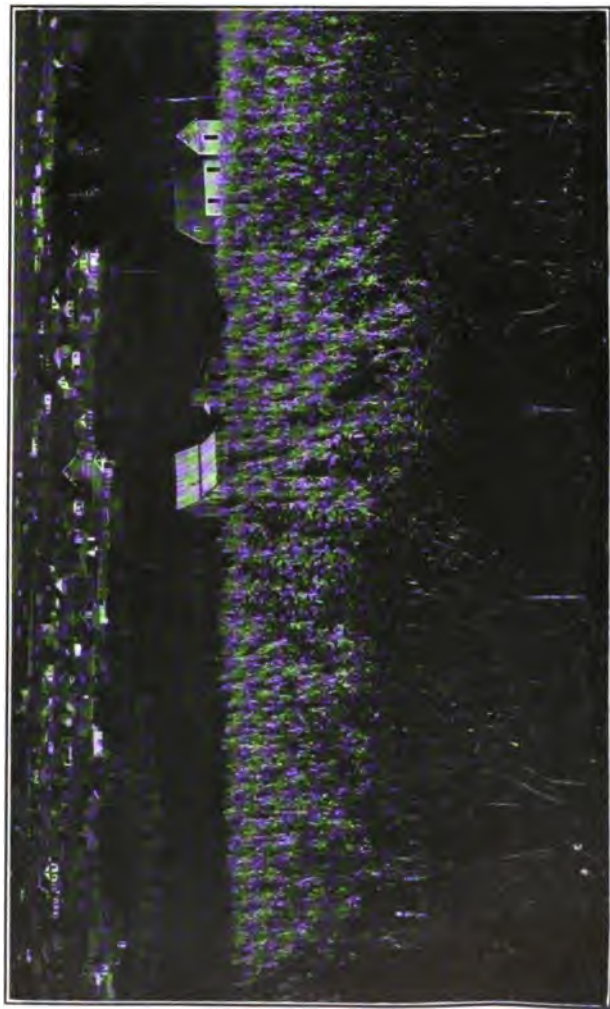
All over the great west this labor of irrigation is going on, sometimes alone, sometimes in combination with waterpower, sometimes with swamp drainage. About Klamath and Tule lakes, in southwestern Oregon, an enormous irrigation project is under way which involves the draining of a great area of lake and overflow lands. In many places, as in the Tieton project in the Yakima Valley, the flow in the natural stream has been exhausted by previous work, and it is necessary to create storage for the full amount of water desired in the new work, and to use nothing but the otherwise wasted floods; yet this flood water

THE CONSERVATION OF WATER

is after all the most abundant part of the supply.

This exhausting of the natural flow, and the conflict of waterpower and irrigation for the use of water, bring sharply to us the problem of the title to water — water ownership — which has already created an astounding situation in Oregon, in California and in Montana, and which requires careful study and a difficult rearrangement of many of our laws.

Most of the problems of irrigation have been solved; but the benefits are just beginning to accrue. More than two million acres have been or are being put under water by the Reclamation Service alone. In Idaho nearly as much more is being irrigated under the terms of the Carey Act, and in Washington and Oregon similar amounts will shortly be taken up under Carey and private irrigation laws and turned into homesteads. If only thirty million acres out of the whole west were so treated the result would be to produce new homes for fifteen million people, besides those who will populate



APPLE ORCHARDS IN THE YAKIMA DESERT

APPLE ORCHARDS IN THE YAKIMA DESERT

This is the same sort of land shown in the sagebrush illustration, and was originally covered exactly as that is. Cleared of sagebrush, furnished with water from a river equipped with large reservoiring lakes at headwaters, and planted with apple orchards, it is returning values as high as \$1,000 an acre, and even in exceptional years \$3,000 an acre a year in fruit.

IRRIGATION

the cities which form the markets of the irrigation districts. And these people are farmers of a new type. By the necessity of the case, by the intensiveness of irrigation operations which make ten acres frequently all a family can operate upon, these irrigation farmers develop scientific methods, and become as no other part of our population has ever been, scientific agriculturists. Living in compact communities, they develop along entirely different lines from the settlers on the prairie whose homes were often more than a mile apart. Living in close neighborhood with one another, in what are really extended villages, they have, owing to the irrigation, every convenience in the way of domestic water, electric light and the usual conveniences of a city, so that the communities are attractive to the city-trained population. The dwellers in them are independent. Each man — instead of investing his money in some distant corporation or insurance company which manages it for him, invests it for him and bears the responsibility for it — invests it in his own

THE CONSERVATION OF WATER

land and in the enterprises of his own town, and is responsible for them. Individual responsibility and individual independence increase together. Compact settlements make for better education and more frequent discussion of public questions; and as a result of this form of life we have more active citizenship, better public life and a prospect for the highest development our form of government and of civilization have yet attained; and this is the direct result of Conservation of Water as applied through irrigation.

The product of these irrigated lands are destined to play an important part in the life of the nation, altering the national diet and slowly but surely altering through that the home life of the rest of the nation. Millions of acres of apples and other fruits have been planted. The lands of the Salt River project produce astonishing amounts of dates and oranges. The staple products, wheat, alfalfa, oats, barley, etc., are equally abundant. And it is the abundance of these fruits, and of the

IRRIGATION

vegetables that are raised on the same land, that will lessen the large meat item in the American diet and by substituting fruits and vegetables gradually tend toward a national economy.

CHAPTER IX

CONSERVATION OF THE SOIL

In the two years during which it has been a public policy Conservation has brought forward an astounding mass of information regarding many subjects on which the public was previously totally uninformed. Of these subjects none is less known or more important than that of the conservation and preservation of our soil. Reckless farming methods alone, by the exhaustion of fertility and by permitting continual and increasing erosion, destroy every year many times as much as is turned into crops; and every river in the land carries off to sea a vast amount of earth which represents the best part of our heritage.

The Mississippi alone carries to sea every year enough finely divided silt — the choicest alluvium and the most fertile part of America

CONSERVATION OF THE SOIL

— to spread one foot thick over 350 square miles of land; and this amazing wealth, representing centuries of slow weathering of rocks, abrasion by running water, and accumulation of vegetable mold, is irrevocably lost, either swept away in the Gulf Stream, or deposited upon the bed of the sea. The Savannah and the other rivers of the eastern seaboard run deep red with the stains of erosion, and the Colorado and the other western rivers are equally guilty. The total loss is a billion tons each year. The prevention of this loss is a part of the work of river control which is directly involved in navigation; but it is also a special part of Water Conservation itself, involving the employment of our waterpower, the planting of forests along the river banks and the storage of floods at headwaters.

The erosion of soil is a process which has been going on from the earliest days of the solid earth and has had a very important part in shaping the continent. When the glaciers retreated to the north after the last great glacial

THE CONSERVATION OF WATER

epoch they left behind them mud and slime, bare rocks, morains, refuse of all sorts gathered in their slow advance or ground up under their tremendous mass. The melting of the retreating ice, the continual and torrential rains due to the great humidity of the atmosphere, gathered up this débris and swept toward the sea. When the great lake of the upper Mississippi burst its bounds and ate away its outlet to the Gulf, this débris was carried downstream to fill up the entire alluvial delta of the river from Cairo, Illinois, down to the present gulf shore line; and this entire region of rich silt is the result of erosive process just as it is now the chief victim of the same process.

All over America this process went on, resulting in the wearing down of the mountains, the leveling of the hills, the final definition of the great river systems, until the forest, advancing over the land on the heels of the retreating glaciers, bound the surface of the earth with its roots and stopped the destruction.

When man came and cut and burned away



DISASTROUS TREE CUTTING

DISASTROUS TREE CUTTING

This picture illustrates a common method of sweeping a hillside bare in cutting the forest. The trees are entirely stripped away leaving nothing for seed, and then fire runs through the slashings, burning even the soil. Soon this hillside will begin to disintegrate and the soil will be washed away into the streams, leaving increasing gullies.

CONSERVATION OF THE SOIL

the forests he released this great destructive force of nature again, and allowed the falling water to sweep into the sea the accumulations of centuries of forest growth. Nothing followed more rapidly on the cutting away of the white pines of the Great North woods than the filling up of the navigable channels of our northern rivers with sand swept down from the deforested regions. Lakes and ponds were filled with it also, and reservoiring capacity lost. And nothing is checking this more completely than the work of the Wisconsin forester, who is gathering together his scattered pine lots into a compact and powerful forest army on the headwaters of the rivers of his state.

This destruction of the land following the cutting of the forest is not a unique experience for America. It is a world-wide development, of which Germany and France have had their turn. And we can do no better here than to examine the catastrophe which befell France when the forests of the Savoyan Alps were destroyed.

THE CONSERVATION OF WATER

The wonderful mountains of the south and southeast of France, below Lake Geneva, have from the earliest times been heavily forested. In the days before the French Revolution these forests were strictly protected by national edict. But after the revolution the destruction began, at first in the plain, then ascending the mountain, as each landowner, fearing new changes of government, attempted to turn his property into cash.

Out of these mountains run two important streams and many lesser ones — the two being the Rhone and the Durance. The Rhone was a navigable river of a swift current, emptying into the Gulf of Lyons; and the Durance was its chief tributary. When the forests were cut away these rivers began to receive increasing amounts of sand and gravel, which rolled along in their currents and made bars and obstructions and rapidly advanced the delta. For nearly a century navigation of the Rhone was practically impossible. In that hundred years — and the process is going on to-day — it has

CONSERVATION OF THE SOIL

extended its delta from the point where it had been practically stationary since Roman times, out into the deep water of the Gulf of Lyons more than four miles, and in that advance has ruined the sea entrance to the river. That four miles represents the agricultural land of the mountains swept down and lost in the sea.

But the loss has been far heavier than that. All through the mountains were little villages which had lived for centuries upon the products of the hills. In each village was a waterwheel turned by a steadily flowing mountain stream. The villages were prosperous and contented. With the destruction of the forests all this changed. The streams no longer flowed steadily but came in torrents, wrecking the mills and many houses, and then going completely dry. With the torrents came earth and gravel, so that in several cases villages have been within the past few years entirely buried in the débris brought down by the flood, the business streets being piled six or eight feet deep in gravel and boulders in a single night.

THE CONSERVATION OF WATER

Such destruction as took place in the Alps was repeated in the valley of the Garonne. All along the north slopes of the Pyrenees the shepherds burned the forests off to increase the pasturage. Their hope was vain, for once the forest was gone the sandy soil quickly followed it. The Garonne became unmanageable and so remains, and the sand swept out to sea was borne back by the sea upon the Gascogne coasts and there piled in great dunes which marched steadily inward, overwhelming farms and villages in sand, destroying fields, blocking rivers and brooks, and finally turning the whole of Gascogne into a marsh, a great unhealthy territory known as the Landes, where shepherds went about on stilts to be above the bogs, and people died of the ravages of malaria and swamp fever.

To remedy this, as to correct the troubles in the Alps, France is spending millions of dollars. On the headwaters of the Rhone she is planting forests, planting meadows, setting up all manner of devices to arrest the erosion, and

CONSERVATION OF THE SOIL

most costly of all, in the beds of streams she is building numberless masonry dams to hold back not the water, but the moving bed of the stream itself. In the delta of the Rhone she is spending other millions to make a canal in place of the natural river mouth choked by débris. In the upper Garonne also she is re-planting forests and building the costly dams to hold back the mountains. And on the Gasconne coast she has planted 2,000,000 acres of pine forest on the dunes to stop their traveling, to permit the opening of the drainage streams and to aid the sanitation of the Landes.

These lessons which every country in the world can repeat, and which have led the Swiss and the Germans to develop their Protective Forests upon the mountainsides, we also have had to learn by hard experience. Not only in the mountains but upon our hillsides, where reckless plowing by the farmer in land which should be planted to grass or tree crops has often destroyed an entire farming region.

We find this on the hills of northeastern Ken-

THE CONSERVATION OF WATER

tucky, and we find there also a remarkable economic revolution produced almost entirely by this soil loss and the failure either of individual or government to provide against it. Along the Ohio river in the counties of Mason and Bracken and their neighbors, the ground rises abruptly above the river, and tumbles southward and westward in a very uneven but very beautiful hill region.

In this region, about fifty years ago, the first Kentucky crops of White Burley tobacco began to be raised, the plant having been discovered in Ohio and brought across the river. Burley grew well on the hillsides, and paid good prices — as high as twenty cents a pound. In the early days a crop could be grown every second or third year on a given tract but as the fertility was exhausted this extended to every five years.

For a long time the Burley farmers plowed the hillsides, even the steepest of them, and raised tobacco on them. Every time the hills were plowed and the earth loosened the next rainstorm swept the best elements of it down

CONSERVATION OF THE SOIL

into some creek bottom. Gradually the cultivation of Burley extended into Blue Grass, the central counties of the state, where the rich bottom lands produced more than twice as much to the acre. The Blue Grass farmers not only had more to sell but they could raise tobacco cheaper and so competition grew keener and the hillside farmer plowed his hillside oftener and grew poorer and poorer.

One may tramp over the hills and drive over the Kentucky roads and watch them strewing straw and earth in a gully in a vain effort to stop the erosion. One may see a wearied and very poor farmer, with his wagon and mule team, down in the bed of the creek, shoveling into the wagon the earth which the rain has washed down, and carrying it back on the hill-sides to strew it again on his land. Wearisome and little repaid toil! The next rain will undo his efforts.

Three things, which the state of Kentucky must initiate, will restore this soil and make its place permanent and will at the same time

THE CONSERVATION OF WATER

advance the prosperity and contentment of the landowners. One of these, which is a custom in all hilly countries, is the establishment of terraces on the hillsides with proper drainage, so as to check and direct the running water. This is a tedious and expensive process which properly carried out remains for generations with little repair, and which makes this land tillable and productive.

The second is the development of forest tracts interspersed with meadows upon the hillsides, the production of timber crops from fast-growing trees, and of cattle upon the meadows. The tobacco barns turned into cattle sheds, the fields into pasture, will bring new life to the hill counties.

But the third method is even more remunerative and equally useful for the prevention of erosion. It is the substitution of fruit crops for the tobacco crops, a substitution for which Kentucky climate and soil are admirably suited. Hardy pecans, grafted with paper shell nuts, walnuts, butternuts, apples, cherries, plums

CONSERVATION OF THE SOIL

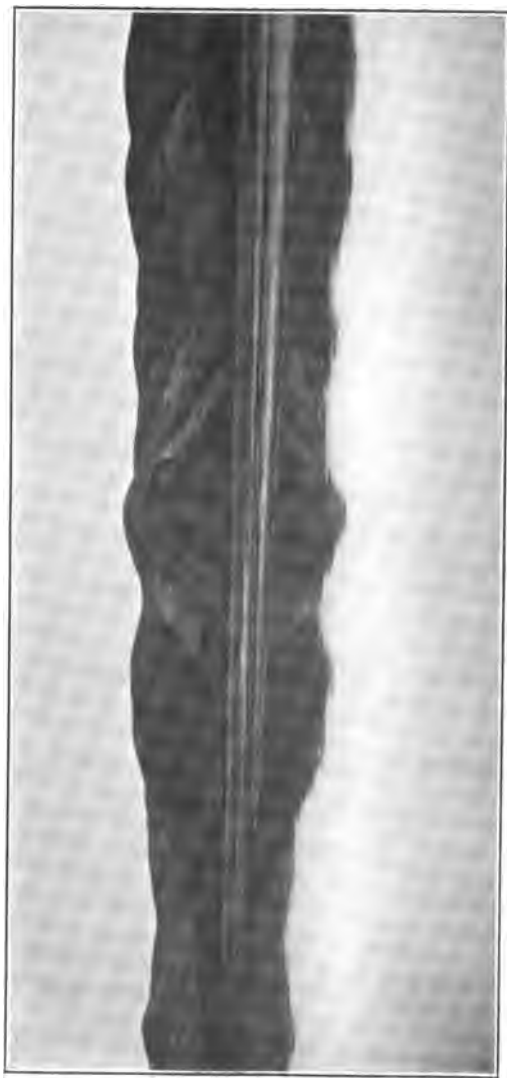
and peaches can be grown there with great abundance and success. On the hillsides their roots will consolidate and bind the soil. Grass grown beneath them will serve for pasturage. The markets for the fruit are close at hand and pay good prices. And with such soil conservation as the state could introduce these hillside farms would grow steadily richer, and pay each year better returns with an entire elimination of the hard and degrading labor of the tobacco field which is now the lot of the farmer.

This hillside erosion takes place in striking extent all along the fall line of the Appalachians, through the Carolinas, Georgia and Alabama, where the sandy red soil is worn into deep gullies, destroying fields and farms, cutting through roads, and burdening the rivers with the elements which are needed in the cotton crop. It takes place on the headwaters of the Tennessee, where the torrential rivers, sweeping down from the deforested hills into the Doe, the Nolichucky, the French Broad and

THE CONSERVATION OF WATER

the Holston, overwhelm the little bottom land farms with gravel, carry off the thin soil which the mountaineers have tilled, and leave waste and ruin where they found contentment and plenty.

The worst example of it all is in the valley of the Mississippi to which I have referred. Throughout the entire course of the running water of the Missouri-Mississippi from North Dakota to the Gulf of Mexico the stream is continually tearing at its banks, dissolving, overwhelming, undermining. The richest farm lands in America line these streams, and fall into them, sometimes an acre at a time. Drifting down the Mississippi I have been aroused in my boat by a roar like a continual thunderstorm, to discover, a mile or so away, a forested bank caving into the river, the rich earth falling away, the mighty trees, a century old, crashing over one after another into the stream. I have seen a mass of land an acre in extent and standing forty feet above the level of the water, fine black soil all through, able to produce more



RIPARIAN EROSION

RIPARIAN EROSION

The barren hills which border the upper Missouri wash down with every rain and clog the channel with silt. Two principal wrongs are done thereby. We lose the soil and we lose the channel. Forests planted upon these hills will in time bind the soil, return a revenue, and reserve beneath their shelter considerable volumes of water to replenish the river in the dry season.

CONSERVATION OF THE SOIL

than a bale of cotton to the acre, suddenly and without warning crack loose from its neighbor and sink swiftly and noiselessly beneath the surface of the Mississippi. Such slips occur not occasionally but daily in a thousand places on the river; and the result is to shift the channel, to endanger navigation, and to bring a heavy loss upon the landowners adjacent to the stream. Thousands of farmers have been rendered homeless and poor by this theft of their land. Within a few years at Point Pleasant, Missouri, the Mississippi has moved sideways two miles, swallowing up a strip of land two miles wide and ten to fifteen miles long, with all the farms, houses and cotton gins which stood upon it. This was rich and productive land, capable of producing all told probably 15,000 bales of cotton each year; but it has been entirely lost and in place of it the river will build up a sand bar, on which it will take a century of silt-depositing to make land equal to that destroyed.

Of all the soil loss in America this from our

THE CONSERVATION OF WATER

river banks is the most easily stopped. In order to transform the Mississippi into an orderly stream suited for navigation it is necessary to fix its banks in place so that the water will always flow in the same channels. This problem the engineers have worked out in detail, and for thirty years they have been applying the solution under niggardly appropriations in a few scattered localities. It consists briefly in covering the bank against which the current strikes with a mattress woven of willow brush and galvanized wire, which we will describe in the chapter on navigation. This mattress is impervious and no earth can slip, slide or be eroded from behind it.

Above low water line the forty-foot bank is sloped back to a gentle angle and covered a foot deep in broken stone. This whole process is called revetment, and is the standard and the only method of withholding this soil from the river, of saving the levees from destruction, of protecting the farmers and of establishing a safe navigable channel. Such revetment prop-

CONSERVATION OF THE SOIL

erly constructed is almost perpetual and needs very little repair in the first thirty years of its existence. In a few years the movement now under way will lead to the construction of at least eight hundred miles of such work on the Mississippi below Cairo alone, and fully as much on the lower Missouri.

Erosion on the hillsides is more difficult to contend with; but in the main it can be greatly reduced by the methods outlined for Kentucky. The steeper hillsides should never be plowed, and since soil loss is a state and national loss the state will some day assume the right to say that they shall not be plowed. Then they will be planted to berries, to vines, to forests, to orchards, to pasture, or otherwise so conducted that a vegetable covering of some sort shall hold them intact. The real purpose of this is double — first to bind firmly the surface of the soil to prevent its washing away; second, and perhaps more important, to retain upon the surface a soft mulch of absorbent earth into which the rain will sink and be absorbed as it

THE CONSERVATION OF WATER

falls, instead of rushing swiftly away over the surface.

The gentler hills and the rolling country should be plowed along the contours, so that each furrow lies level and affords a holding place for floodwater until it sinks into the ground. The plow and cultivator passing along such furrows close the breaks in them and keep them tight. All through the cotton country this contour plowing is spreading with beneficial results; and one may travel for miles through Georgia and Alabama and see everywhere the winding rows following in and out the curves of the hillsides. This work, however, should be seconded by "balks" or strips of unplowed land, parallel to the furrows also, at frequent intervals, but left unplowed to check the gullies that may start and to afford a holding place for depositing the earth which has started to wash. Such balks in a hillside maintained for several years tend to form terraces by the gradual accumulation of earth upon them, and in fifteen or twenty years the

CONSERVATION OF THE SOIL

farmer finds his field approaching a condition of level benches following the curves of the hill.

These measures, including those of silviculture above, are, after all, concerned with the mechanical depreciation of our soil; and on level ground they should be supplemented with good drainage which will keep the soil always in condition to hold and absorb rainfall. But there is another sort of soil depreciation which has already reduced the crop production of the country to a remarkable extent, and that is the over-cropping without fertilization. Every field which is planted continually in one crop year after year exhausts the elements which produce that crop; or disturbs the balance of elements in the soil so it will no longer yield them; or sets up in the soil some actively opposing element, sometimes a plant poison, which prevents crops of that character prospering. It was this which the Ozark backwoodsman had in mind when, looking regretfully at the half-acre clearing which had been his only corn sup-

THE CONSERVATION OF WATER

ply for forty years, and in which a few yellowish stalks were trying to grow, he said:

“That were a good bit of land, fifty year ago — but she done been corned to death.”

From New England to the Pacific coast there is not a state in the Union in which some land has not met the same fate. New England is filled with abandoned farms, abandoned solely because they would no longer without proper care produce the old crops in abundance. New York is filled with them, and the abandonment is spreading westward. But every once in a while someone who knows comes to an abandoned farm and by skillful cultivation turns it into a magnificent producer. In Illinois there are farms cultivated under the old, shiftless fashion which do not produce over twenty bushels of corn to the acre; and immediately adjacent to them farms of no better soil, but of better management, which produce seventy-five to a hundred bushels of corn in the same area. Land in the South is frequently classed as “bumblebee” because it will not pro-

CONSERVATION OF THE SOIL

duce anything but the scraggly remnants called by the farmer bumble-bee cotton; and yet the same land properly taken in hand may be made wonderfully productive. There is, for example, at Rome, Georgia, a school for mountain boys where they are taught agriculture. To this school come the unlettered mountaineers who have never seen any form of agriculture other than the continual light plowing of the hillsides with its swift erosion, which produces a few bolls of cotton and a little corn for the mountain family. They come to a school which has for its cotton fields abandoned land "cottoned to death" before the boys come to it; and there they are taught to plow deeply, to stir up the better elements below and to return the old plants deep into the soil for new nourishment. They are taught to put on fertilizer suited to the soil, and put it in abundantly — and to make the cattle barn provide this plant-food. And as a result they see this abandoned and exhausted land returning every year better yields, soon to produce a bale to the acre, then

THE CONSERVATION OF WATER

to reach a bale and a half, eventually, without doubt, to produce two bales to the acre on the sandy flat lands of Georgia.

This matter of the internal economy of the soil is one of the least understood by the farmer, by the public and even by scientists. No more important work is being carried on to-day in our country than that of the Bureau of Soils, in the survey and examination of the soils of every state, and the tests made to determine the action of these soils under widely varying conditions. It has long been a common theory that the plants were nourished on mineral constituents in the soil, and that if an abundance of phosphates, nitrates and potash were added to it the plant would select them for food and increase accordingly. If an opposite result were obtained (and it sometimes happens that the wrong fertilizer reduces the yield of a crop with startling quickness) the farmer affirmed that it had "burned" the crop, and used less next time.

As a result of this theory we have been over-

CONSERVATION OF THE SOIL

whelmed by the prediction that our soils would be chemically exhausted in something like one hundred and fifty years and we would then, as a nation, starve to death unless we found new ground. Nothing could be more baseless than such predictions. Soil is not merely a matter of mineral elements to be subtracted by the plant; it is a dynamic thing, a moving body, continually alive, added to by the winds and the rain, moving about with the running water, disturbed by earthworms and insects, aerated and oxygenized by plowing and cultivating, never remaining long in the same condition. It contains not only the plant-feeding minerals and many others, but also a percentage of organic matter, continually varying in nature and in action. Over the country at large there is in the surface soil an average of more than two per cent of organic matter; and this matter is as likely to be harmful as it is to be helpful to the growing crop. Part of the work of the Bureau of Soils consists in the examination of these organic elements, and the discovery of

THE CONSERVATION OF WATER

which of them are harmful and how they can best be removed or counteracted.

Southern Illinois possesses as rich a soil as one can find anywhere, heavy black, clayey loam, which requires strong underdrainage, deep plowing, continual cultivation to keep it in condition. Instead of producing twenty-five to thirty-five bushels of wheat to the acre as such soil ought, and as it does elsewhere, this southern Illinois land produces on an average only about eleven bushels of wheat. Examination by the chemists found nothing lacking of the so-called fertile elements, but too much organic matter of an evil nature present. Owing to the internal reactions the soil was what is called a "sour" soil, unsuited for growing wheat. Over its surface is being spread, and deeply plowed in, finely powdered limestone, practically a lime flour. The effect of this is neither to add food for the plants, nor to release the fertile parts, but to alter and better the action of the organic elements in the soil and so bring about more favorable condition



HILLSIDE EROSION

HILLSIDE EROSION

This is a typical illustration of the condition of the majority of the hillsides in the Carolinas and Georgia, where the pine forest has been swept away. It prevails in many other states. The sandy soil washes rapidly away under the torrential rain, and large areas are thus destroyed. Only the planting of shrubbery on this hillside will stop this erosion. The wasted sand fills the river channels and causes floods and aids to destroy navigation.

CONSERVATION OF THE SOIL

for growth. The result of it is to increase the wheat yield to about twenty-six bushels an acre.

This increasing of the fertility of the soil is not directly an element in the Conservation of Water, though it is in the larger Conservation. But because of the fact that the amount of water working in the soil, the drainage and cultivation and their effect upon the moisture conditions are vital elements in the restoration of the proper balance of elements to secure large crops, they have a place here also. The measures which are taken to correct the bad conditions go hand in hand with the measures described earlier in this chapter for the prevention of erosion. As they advance together in the development of a scientific farming which shall take them both into equal condition, the loss of fertile parts of the soil from washing will diminish rapidly. As it diminishes the billion tons which now wash annually into the sea will steadily decrease, and with that decrease will go also a reduction in the trouble we now have in maintaining channels in our rivers

THE CONSERVATION OF WATER

and keeping cut away the bars at their mouths. Purer water in the rivers will improve the municipal supply and lessen the troubles of the cities; and the reservoiring effect of the terraces, the hillside groves and orchards, and the deep plowing in the level ground will have an appreciable effect upon the high and low water régime of the rivers.

CHAPTER X

NAVIGATION

No other method of carrying freight yet devised by man compares in efficiency or economy with stable and well-developed water transportation. That is true not only on the sea, and on the Great Lakes with their deep channels, it is also true on rivers and even on very shallow rivers. Though depth of channel is an important aid to economy, rivers less than three feet in depth can be made to carry large and slow moving cargoes at a cost far below that of the railroads.

In an unstable or irregular channel this is not possible. The elements which enter into the cost of transportation are the terminal handling of freight, the operation and maintenance of the fleet and the insurance on vessel and cargo. Terminal docks, equipped for eco-

THE CONSERVATION OF WATER

nomie freight handling can only be erected where the bank of the river is stable and certain not to allow the heavy investment to slide into the stream. A fleet to have a low cost of operation and of maintenance must be entirely of steel, representing a large original investment, and such an investment is only justified when the channel is sufficiently stable and clear so that there is a certainty of employment and of safe journeys practically every day in the year. Insurance on wooden vessels in an unstable channel often more than offsets — sometimes figures more than double — the difference between rail and freight rates. It can only be reduced to a nominal sum by the use of high-priced steel equipment and the absolute certainty and stability of the channel.

A fixed and stable channel, therefore, is a necessity for navigation. It requires, besides, to be of fairly normal flow having neither disastrous floods nor prolonged low water seasons. Depth of water is the final desideratum. It is therefore one of the most natural and impor-



A WELL-ORDERED RIVER

A WELL-ORDERED RIVER

This view of the Rhone, looking down stream from the bridge at Avignon, shows how our rivers may be made beautiful at the same time that they are rendered useful. This river of tremendous floods has been bordered by stone levees, its banks revetted to prevent erosion, and grass planted between the revetment and the levee. The bridges are handsome structures, everything by the stream is permanent, and the improvement of the channel has led it into gentle and lovely curves.

NAVIGATION

tant departments of the Conservation of Water, and we shall see that it is closely linked up with every other division of this work.

Rivers suitable for navigation fall, in general, under one of two classifications, soft bottom and hard bottom. The Ohio, during most of its course is a hard bottom river; so for a considerable distance, is the upper Mississippi; the lower Mississippi and most of the Missouri are soft bottom rivers. These two sorts of rivers require for their development totally different local works along the stream, but exactly similar general works at headwaters and on the tributaries. We will consider their differences first and their similarities later.

A hard bottom river is one which has worn its bed down to the rock. Sometimes it flows gently in this rocky channel, sometimes it tumbles and rushes pell-mell. Year after year it flows in the same course with very little change. If it is a gentle river of little slope and abundant water it is improved by what is called the "open channel" method; its channel is con-

THE CONSERVATION OF WATER

tracted so that at low seasons the water is confined to a definite midstream section giving it less surface and more depth. Rock and other obstructions are removed and a clear deep way provided. This is the work which has been done for many years on the Ohio, in advance of the lock and dam system now being installed.

The contraction of the channel is obtained on the Ohio, as it is on the Danube and on many other hard bottom streams, by means of long lateral "dikes," ridges of stone high enough to confine the low water flow but low enough not to hinder the high water discharge. These dikes are based upon some rock upon the shore, and extend out into the stream at an easy downstream curve as far as seems desirable, and then turn and parallel the thread of the current sometimes for half a mile. The space back of them segregated from the river bed gradually fills with sediment in a muddy river; but in a clear water stream often forms a protective harbor. Dredging, blasting out

NAVIGATION

rock and otherwise making uniform the bottom of the channel completes this "open channel" method in a hard bottom stream. It consists, so far as the middle stage river is concerned, in simply narrowing and clearing the trough in which the water runs.

But many rivers with hard bottoms have too much slope to be treated in this way. They are so steep that the water runs down them faster than it is supplied and leaves them very shallow. This is the case with the Ohio, which in the reach from Pittsburg to Wheeling falls more than a foot to the mile and is equally steep in other short reaches. Such a river must be developed by the method known as canalization, or slack-water navigation; and this method is applied to nearly all hard bottom streams in some part of their career.

In its simple terms canalization consists simply of erecting across the river at suitable intervals dams which hold back the water from the position of one dam to the foot of the next above, forming a pool in which there is at low

THE CONSERVATION OF WATER

water almost no current. This pool has a surface elevated several feet above normal low water and therefore has a channel that much deeper. At one end of the dam a short canal is built having in it a lock, or a chamber of concrete large enough to hold a vessel, with gates at each end, water tight, for raising and lowering vessels between the different levels.

In a river so equipped even a small flow at low water is held in the channel and preserves navigation. Time is lost in passing the locks, but it is regained in the upstream travel by the lack of opposing current. In a river like the Ohio, however, which fluctuates sixty-five feet vertically between high water and low water, a fixed dam standing across the bed, high enough to be of value at low water would begin to be a nuisance as soon as high water came. Until the water was high enough to give full depth for vessels over the dam it would prevent their passage, and even then it would create a disturbance in the channel, hold up the flood and tend to create a greater overflow. So there has

NAVIGATION

been invented a movable or collapsing dam — adapted from the French — which obviates this trouble. This collapsing dam on the approach of a flood is thrown flat upon the bed of the river thus making the river during the deep water period an open channel stream.

These collapsing dams, of which it is planned to erect more than fifty in the Ohio, are of several types. The Chanoine Wicket is the commonest of these, consisting of panels four feet wide and as high as necessary, standing upright in a row to form the dam, each braced against a prop in the rear. Withdrawing the supporting bar from under these props, or tripping them from above lets each panel in turn fall back flat upon the river bottom.

Another type is the needle dam, such as is used in the Big Sandy river at Louisa, Kentucky, which consists of a collapsible steel bridge, against which, when it is erect, square timbers are stood on end side by side to form the dam. These square timbers are the "needles." The flow of water past such a

THE CONSERVATION OF WATER

dam is often regulated by a "bear trap" — a sort of hinged flashboard made to rise or fall at the will of the attendant by the pressure of water above it, and as it rises or falls lessening or increasing the flow of water through the spill-way.

These dams are excellent for navigation; but they are absolutely useless for the development of power. They are not tight. Much water escapes through them. And owing to the fact that they only stand at odd intervals of low water they will not produce any steady and marketable power which will pay for equipping them with turbines and generators.

Considered therefore from the point of view of the Conservation of Water such dams are a failure — a makeshift. And that is what we find them to be. So long as the floods persist, so long as the Ohio is permitted to range from a mere drivel to a destructive torrent seventy feet deep, and to overflow cities and farms, destroy mills and stocks of goods, end commerce during the floods and prevent the development



A LOCK ON THE ILLINOIS

A LOCK ON THE ILLINOIS

Wherever a dam is erected in a navigable river, either for the purpose of deepening the channel or for generating power, it must be equipped with such a lock as this for passing vessels from one level to the other. This grass bordered lock, in a river of gentle slope and permanent bed, is typical of what we may expect when all our rivers are properly conserved and cared for.

NAVIGATION

of power—so long these dams will be required. But when actual Conservation begins to preserve the valley from floods, to maintain a steady river, to develop the power and to reduce soil erosion — when these things are done and the Ohio is normalized, a concrete dam will replace each of these, a power house will stand beside it, and the Ohio from a drain on the national treasury will become a liberal contributor to it. We will return to this later.

Soft bottom rivers are of two principal sorts. The Illinois, for an example of one sort, is a very soft bottom river which holds its banks firm and maintains year after year the same stable depth. It has not, as a matter of fact, an equal for its stability and uniform behavior. It can be dredged and the dredged channel continues at the new depth. The banks and the current seem to have reached an agreement by which neither interferes with the other.

The very opposite is true of the Mississippi. Its banks are built of friable alluvial soil, and its

THE CONSERVATION OF WATER

current is swift and powerful. Consequently the Mississippi below Cairo, in every bend, tears at and devours its banks almost continually. Sometimes the soil falls in by hatfuls, sometimes by acre slices, as we have seen in the chapter on soil preservation.

This earth which the river picks up so avidly and which it steals from the riverside farmer, it carries but a little way and drops in the next crossing — where the current moves from one side of the river to the other. Dropping it in the crossing forms a bar, which obstructs the river and changes its course, and sets it to tearing out its banks in a new place. As a result it is continually in motion, shifting its channel and obstructing navigation with new bars. These movements, however, are more or less systematic, so that there are below Cairo only about twenty bad bars which give trouble to navigation, while in the bends which constitute most of the river the water is from fifty to one hundred and seventy-five feet deep.

It is perfectly evident that in a river which

NAVIGATION

shifts its channels, changes and creates bars and caves its banks, neither stable terminal docks, nor a secure navigable channel can be maintained without some radical development. This development we have already considered as a measure of saving the soil. It is the revetment of the banks. In every bend there must be placed a brush revetment. Willows cut from the numerous towheads, in which they grow in rank abundance, are cut when they are about twenty feet tall, and are brought in boatloads to the scene of operation. There they are made into bundles called fascines, each about two feet in diameter, and by means of galvanized wire cables these fascines are stoutly woven into a mattress, the cables being used as weaving threads, the willows as the cross threads. If a grass or rush carpet could be viewed under a gigantic magnifying glass it would appear like one of these fascine mattresses. Lying upon the surface of the river when completed they are often three hundred feet wide and a thousand feet long, the inner edge lying on such

THE CONSERVATION OF WATER

a line that if the river were at dead low water it would be exactly on the shore line — called in river work the zero contour. When it is thus completed the mattress is loaded with rubble stone and sunk against the under water bank, where it lies like a blanket, protecting the soil from the action of the current. No earth whatever can be drawn out through such a covering, and on the contrary the river fills the interstices with silt so that it becomes a solid mass and imbedded in the bank. There it will remain practically perpetually without alteration or repair except in the case of some unforeseen accident such as a vessel dropping anchor into it. It holds the bank exactly in place and keeps the river in a steady channel so that the bar in the crossing below the bend is scoured out and the channel deepened.

When the mattress has sunk into place hydraulic graders come into play and the vertical bank overhead is sloped back about three feet horizontal to one vertical so that the forty foot rise has about a hundred and twenty feet of

NAVIGATION

surface. This is then covered a foot deep in rubble stone, the place where it joins the mattress is well reënforced, and the task is done. Thenceforth that bend will remain stable, and the farmer on the bank above can be certain that the river will not take his farm.

Even if we had no care for navigation whatever, even if we did not intend to run a ship or to carry a cargo, this revetment would be absolutely essential, and we would be compelled to create it to save our rich farming land in the bottoms. It is to cost all told, systematically carried on from Cairo to the sea, something between \$75,000,000 and \$90,000,000 to which Congress now appropriates \$4,000,000 a year beginning in 1910. When it is done the flood levees will be advanced to the river's edge (for the further benefit of navigation) and the crops produced on the protected land will every year more than repay the entire sum spent on the work.

This revetment work is the necessary work for producing a channel in the lower Missis-

THE CONSERVATION OF WATER

sippi. When it is all done the river from Cairo to the sea will be automatically deepened at all points to twenty feet, and the navigation will be certain and stable. But after all it is only a makeshift too, like the temporary dams on the Ohio. The caving of the banks is due largely to the constant fluctuations in the speed and level of the water. Banks soaked in flood time fall of their own weight as the water leaves them; and bars filled in during the flood upset the low water channel and cause the river to devour its banks. For further stability of navigation and to remove the cause of the trouble we must eventually keep the river below the bankful stage. Reservoiring the Ohio will do most of this, for the Ohio is the greatest flood producer of the system. But the Missouri, the upper Mississippi and the other tributaries must be reservoired as well to produce the combined effect.

These methods which I have described here apply in larger or smaller degree to every river in America. Now let us see what we get from



A REVETMENT MATTRESS

A REVETMENT MATTRESS

The Mississippi and the Missouri Rivers are continually eroding their banks, changing their courses, destroying farms, and filling up their channels with the wasted earth. The only way to stop this loss and establish navigation is to "revet" the banks, a process on which the government is engaged. This shows a willow mattress, woven together with galvanized wire cables, the completed portion floating on the water. These mattresses are often 300 feet wide and 1,000 feet long. When completed they are loaded with stone and sunk against the under water bank, where they lie permanently, preventing the river from eating out the earth. The upper bank is then graded to a gentle slope and covered with broken stone.

NAVIGATION

them and how we extend them, aside from this protection by revetment.

The reservoir system for navigation must consist of great storage basins at headwaters, and of forested hillsides above the reservoirs — and we find this is the same storage of water, the same Water Farms which are essential for the development of power, for flood protection, for municipal supply and for irrigation. They require no additional quantity for navigation, no alteration in operation, no change or additional expense whatever. But let us see what they will return on the Ohio. This river has a total available fall which can be transformed into power of nearly 500 feet. It has an average flow of 158,000 second feet. If we sufficiently normalize the flow on that part of the river above the Tennessee to secure a constant discharge of 40,000 second feet so that that amount could be made the basis for power development, we would have at fifty fixed dams, of ten foot head each, 1,800,000 electric horsepower — and it is certain that the river could

THE CONSERVATION OF WATER

be normalized to 80,000 second feet so as to produce not less than 3,500,000 horsepower. Figuring only on the first estimate the power is worth at the lowest wholesale prices, nearly \$50,000,000 a year.

We have spent on the Ohio more than \$40,000,00 and we propose to spend twice that hereafter in completing a system of movable dams which will give us a navigable channel but no other return whatever and which will still be subject to floods and droughts. But here we have Conservation applied to the same channel. If we issue bonds for the work to be repaid over a long period, and if we employ those bonds to create storage what will be the result?

Let us assume that the Ohio has no water at all during low periods and that through four months in the year we must create a river of 40,000 second feet simply by releasing the water from reservoirs. That will require 335,000,000,000 cubic feet of water stored in the mountains — nearly four times as much as

NAVIGATION

we have stored now in the Mississippi. But this amount is not enough, for there are some years of double floods and some of longer droughts. We must nearly double it—to 600,000,000,000. Storage on the Mississippi cost \$14 per million feet. A good average price for expensive storage on the Ohio would be \$100. But let us double this and go at a very high price, and estimate the cost at \$200 per million feet. It would be but \$120,000,000 for a protection from floods which would save the Ohio Valley ten to twenty million dollars every year. Then we must erect fifty concrete dams and the adjacent power houses at \$4,000,000 each — which will cost us \$200,000,000. Altogether this involves less money than the Panama Canal, but unlike the latter it pays its own way. We have spent but \$320,000,000 and we need to add but \$50,000,000 to this for the electric distributing system and all that goes with it, and we shall have our waterpower returning big dividends to the nation.

Instead of expending \$100,000,000 with no

THE CONSERVATION OF WATER

return for a navigable channel, and still suffering from floods, Conservation proposes that we shall invest five times as much — the equivalent of the cost of the Panama Canal — for a bigger work, avoid the floods, increase municipal supply, prevent soil erosion, save the power and have an income, gross, of 13 per cent, net of probably 9 per cent on the money invested, to retire the bonds.

We are dealing in big figures, but with a big subject. Hamburg in Germany has spent \$100,000,000 on its harbor. Bremen has spent nearly as much. We have ourselves spent \$250,000,000 on the Mississippi system simply working at it in the old-fashioned back-handed manner which spent the money for navigation alone without return and gave away the by-products. Now we propose to spend the money on other things that pay big dividends, and let the navigation come as a byproduct of them all. Let us apply this method to the greatest of American waterway projects and see where it brings us and what we have already accom-

NAVIGATION

plished. I refer to the Lakes-to-the-Gulf channel, the route for ships from Chicago to New Orleans which it is proposed shall be at first fourteen and later twenty feet in depth.

This channel begins in Chicago with the Sanitary Canal. That canal has cost Chicago all told nearly \$60,000,000 and when it is in full operation it will return from waterpower \$750,000 yearly, from rentals along the bank not less than \$1,000,000 (rentals made possible by the deep waterway) and eventually \$2,000,000. Its sanitary value to Chicago alone, in the reduction of the death rate has made it money well spent.

The next section is a drop from the end of the Sanitary Canal to Utica, a fall of more than a hundred feet. In this reach more than 100,000 electric horsepower can be developed and Illinois has voted to spend \$20,000,000 on the conservation of this waterpower for the use of the state, the navigable channel being a byproduct. The waterpower will return not less than \$2,500,000 annually to the state, first paying off

THE CONSERVATION OF WATER

the bonds, then giving her a surplus for other improvements.

The reach from Utica to Cairo will involve three great dams, one at Alton and two below St. Louis. Each of these will generate 200,000 electric horsepower and the total result will be power worth about \$16,000,000 a year, to repay channel and electrical construction of not over \$100,000,000. The reach from Cairo to the sea we have already considered.

So here we have a magnificent illustration of the Conservation of Water in which the several elements, waterpower, flood protection and soil protection are the principal parts of the work; and return liberal dividends; while the navigable channel is a free gift to the people of the nation.

This is the new idea of navigation. It came upon the engineers suddenly when President Roosevelt proposed his great doctrine of Conservation. But it is bound to sweep through the country. And it is certain that there will be no more granting of waterpower privileges



STEAMBOATS ON THE UPPER MISSOURI

STEAMBOATS ON THE UPPER MISSOURI

Owing to the erosion of its banks, as shown in the foreground, the Missouri is navigable in its upper reaches only to these small boats. When the power at the Great Falls and above there is properly taxed, and the money applied to the revetment of the banks, large, steel boats adapted to shallow channels will be used here. The banks of the river are lined with lignite coal, and this and grain will provide large cargoes.

NAVIGATION

in navigable streams, no more alienating of power-sites when the idea has become established; but that these public works shall be carried out as public enterprises and the returns flow into the Treasury.

We have devoted much space to the Mississippi system. On the Columbia where the interests of Irrigation, Power and Navigation are all bound up together with the problem of storage, and Conservation, we could point even a more brilliant example. The Tennessee, the Coosa — remarkably so, the Coosa — the Peedee and the other rivers of the seaboard, the Hudson on which the state of New York is planning tremendous storage — all of them offer the same opportunity and the same results. In the end every one of these rivers and every little river in the land will be improved from the Conservation standpoint, and not from that of navigation. But navigation will be the sure result.

Navigation means not only saving and economy at home, it means the easy invasion of for-

THE CONSERVATION OF WATER

eign markets. To the farmer in Dakota it means five to twelve cents more for every bushel of wheat, the saving in seaboard freight by water down the Mississippi will be fully that when the river is improved. That means \$300 to \$500 clear gift to every farmer of a quarter-section every year. The manufacturer will reach his customers more easily. The burden of coal and lumber taken up by water will release railway cars for better freights; and cheap fuel and cheap raw material (and abundant waterpower) will stimulate and increase manufacturing. That is what makes a nation prosperous. That is what gives us opportunity to reach South America and the Orient. It is as if instead of leaving Panama finished at the Isthmus we extended it up into practically every state in the Union so that cargoes from little inland towns could go to it as freely as they go from Mannheim on the Rhine or from Breslau on the Oder — or from New Orleans or New York.

CHAPTER XI

THE RESULTS OF THE CONSERVATION OF WATER

We have come the whole road now, from the first establishment of the Water Farm, through the several processes of swamp drainage, irrigation, the development of power, the revetment of the bank, the purification of the rivers, the establishment of navigation, the conservation of the soil, to the full accomplishment of the best use of water. Let us look about us and see into what sort of a country the journey has led us.

Truly it has brought us into a beautiful land. We enter it at the sea gate, at the mouth of a great river, where we find a port bustling with commercial activity. Magnificent stone quays, lined with great steamships, equipped with powerful machinery, and provided with hand-

THE CONSERVATION OF WATER

some warehouses, — these greet the eye. Back of them lies the Gate City, fronting the river above the port with beautiful parks, grassy and well wooded. The air is clear and free from smoke, the walls of the buildings are white and clean, the trees are green and fresh. It is a far cry from the smoky, grimy, unkempt city of to-day.

“Magnificent docks!” So you cry. “But what an amazing expense! How can the people bear such taxes?”

“No expense at all,” replies the citizen. “We have conserved our river and it is now steadily navigable. Therefore we have an enormous commerce. Bonds for enough money to build our port, extended over a long period of years, are repaid by a light charge on the increasing traffic. This is part of our reward for taking care of our running water.”

“But why is the city smokeless? Have you no manufactures?”

“We manufacture for the export trade in great quantities — but the power all comes by

RESULTS

wire from the dams which make the river navigable."

So we go on, wondering, through this beautiful city. At every point we stop to exclaim and admire the public buildings, and we learn that they, too are a gift from conservation, paid for out of the public income from the services of water. We drive to the dock to take a passenger steamboat for the interior, and find this, too, a public dock, as well equipped as the best railway station. A handsome steel steamboat awaits us and carries us up the river.

As we advance into the interior our wonder grows. The water of the stream is limpid and clear. The banks, gently sloped, are faced with white stone in the swifter bends, but in the other parts are covered with rich green turf. On each side the banks are well curved and regular, and there is a total absence of the old time horror of caving land, of snags and overhanging tree-roots, of sandbars and wasted land. Instead the regular channel is fronted with rich and well tended farms and occasional groups

THE CONSERVATION OF WATER

of trees, and the land is crossed by fine roads bordered by rows of shade trees.

“What has brought all this about?” you ask in wonder. The answer is always the same. Protection of the soil by revetment, proper regulation of the channel, these have established and perfected the river. Water Farming which has put an end to floods, has stopped the caving of the banks and made the lands on the bank magnificent home sites. The example of the carefully tended river has made the people more careful with roads and land. Stone brought down from riverside quarries has made cheap roads, and careful tillage and conservation of the soil has made a small farm sufficient for a family; so that we have, as we see, practically a continuous village stretching along the river, like an extended irrigation town. The swamps are drained, the overflow has ceased, the forests are cleared or brought into the condition of a tree-garden; dilapidation has given way to perfection.

City after city as we pass it presents the

RESULTS

same condition of cleanliness, the same rows of magnificent docks well equipped to handle traffic, the same freedom from smoke, the same elaborate public buildings and parks — the people, the same appearance of prosperity and contentment that we saw in the Gate City. Up and down the river move continuously fleets of barges, fast package freight boats, fast passenger steamboats, all moving swiftly, all smokeless — for the care of fuel has advanced with the care for water — and all of new types, developed since reliability developed in the river channel.

Commerce with all the world is plying in these barges to be interchanged at the Gate City. For the easy manufacturing made possible by cheap and abundant waterpower; the facile transportation furnished by the deep and stable channels; the rapid and economical interchange at the Gate City made possible by electric power and efficient public docks — all these make plain and smooth the road from the factories in the interior to the ports of South

THE CONSERVATION OF WATER

America, of Africa and Asia, and of all Europe. American goods, and with them American ideas, are going out through all these channels to the world. These points here where the factories stand, these manufacturing centers beside the waterways, these are the strategic vantage points of American idealism. Freedom, intelligent liberty — these things and American humanity go out into the world with commerce, from these water-driven mills. And their progress like that of commerce is facilitated and made easily possible by the Water Farms we have established.

We come at last to a dam erected across the river. Over the crest of it a thin film of surplus water falls in a lovely cascade, but not enough to hide the dam itself, which is coped with handsome stone work and finished as carefully as if it were an ornamental work in a public park. At one side are the locks for vessels — a long, wide lock, 100 by 1000 feet, through which a whole fleet of barges can pass at a time; beside it a lock 75 by 500 for passing through

RESULTS

the swift packet and passenger boats. At the other side, incorporated into the dam is the power house, a white concrete structure built low upon the dam, with its red-tile roof furnishing an element of contrast that brightens the scene. The lock walls are surrounded by a grassy park, filled with trees. There is not a break in the perfection of the channel work. Below the dam on one side is a row of docks equipped with handling machinery, and a group of mills, flanked by a small residence section of concrete, working-men's houses, each surrounded by its grass plot — one of the new manufacturing villages with water transportation and electric power to free it from the thralldom of the railway and the city.

Passing through the dam and advancing steadily upstream, past flourishing cities and villages, under permanent and handsome stone and concrete bridges, past scenery of many kinds — rocky cliffs, rounded hills, and broad, gentle valleys — we go; and nowhere do we see the erosion of gullies showing, or the

THE CONSERVATION OF WATER

cutting of a bank, nor do we see the flimsy frame houses of the swamp days with their sides marked by the annual flood line. All that has disappeared, and a well developed country of small farms, well tilled, and handsome farm residences has taken its place.

Something more we notice; for the machines which are gathering in the corn, the plows which are preparing the ground for the winter wheat are all four-wheeled structures driven by electricity. No horses are in sight in the fields, but instead the farmer's engineer rides upon the machine, to which a wire leads from a trolley along the side of the field, carrying current from the power house we have passed down the river. The houses on the farms have chimneys, for the old-fashioned wood fire in the living room is within every one's reach now that the forests are cared for at headwaters and firewood brought down thence and from the protected hillsides close at hand. But if we leave the boat and inspect the farm we find

RESULTS

everything else done by this electric power — the housewife ironing and cooking and heating water with it, the farmer not only plowing but churning, milking the cows, cutting stalks for the silo and hoisting them in, lighting the house and barns, and operating his passenger car and his freight wagons with it.

“If we leave the boat,” I said; and the landing where we leave it is itself well worth our observation. For the farmers in a considerable territory in order to avail themselves of water transportation, have made a service of fine roads reaching out and back for several miles and converging on a single point on the river bank. There they have established a landing dock, with machinery for taking off their produce and for delivering the things they have ordered from city and factory, and there they meet the river barges with their farm motor-wagons in an economical transfer of freight.

Wagons, carriages, dock machines, plows,

THE CONSERVATION OF WATER

are driven by the white coal which we have secured at headwaters.

We find paper mills and furniture factories beside the river, and factories turning limestone and coke into nitrates for the soil, and all these are products of Conservation, the power from the river, the wood from the protective forests at headwaters. And at last, transferred to a smaller steamboat as we approach headwaters, we pass through a pair of locks which lift us seventy feet through a beautiful, lofty, curved stone dam into the first of the reservoirs upon the main stream.

Here we are in the playground of the valley — such a summer playground as every river in America now has. It is the first of the Water Farms, a beautiful body of clear water, surrounded by hills covered with a green and well-kept forest. The shore line grassy from the water's edge to the trees, is marked by frequent landings, and if we were to land at one and follow the path that leads from it it would take us to a log cabin, a bungalow, or a cottage



THE RHONE, A WELL-ORDERED RIVER

THE RHONE, A WELL-ORDERED RIVER

When the banks of a river have been fixed to prevent erosion, they can be surmounted by stone walls to keep back the small floods which still persist, and made orderly and beautiful. This is typical of the well-kept rivers of France.

When we have followed Conservation to its full development, have purified and regulated our rivers, reservoired them against floods, improved their channels, and revetted their banks to prevent erosion, this is what we may expect to see — graceful, curving channels, navigable, beautiful, bordered with grass and trees, or with handsome and smokeless cities, adding to the fascination both of traveling on and of dwelling by them.

RESULTS

in the woods not far from the shore — a private summer home built upon this public ground (or upon private ground, though we may believe that most of this is state forest reserve) and paying a ground rental of but five dollars a year to the state. If we examine further we shall find these houses so sanitary and so protected that no pollution from them can reach the reservoir; and we shall find the people of the cities summering here in healthful, restful surroundings, boating, fishing, hunting in the forest reserve, enjoying the use of their own state property to the fullest extent. One reservoir above another admits our little steamboat till we come to the headwaters. Power house after power house we pass, and the wires that feed the cities lower down reach from them over the hills by short courses to the cities. All through the forests we shall find forest gangs at work cutting out mature timber, machinery erected here and there to carry to the reservoir a year's growth, the waste gathered up and burned or carried to a boat and away to

THE CONSERVATION OF WATER

the alcohol factory, the timber barged down to the sawmills, the paper mills and the furniture factories. Everything put to use, everything designed to give pleasure, nothing wasted — that is the net result of Water Farming as we find it here.

Is it not worth while? Is it not worth study and attention and hard work at the polls, to bring about this situation? This situation in which every river becomes a public asset and its development returns to the people a steady money income? A situation in which this money income pays for public parks and public buildings, spreads out the cities into the country and gives us public health; turns the sewage into healthful fertilizer and gives us cheaper living; turns headwaters into paying forests and healthful playgrounds for the people, and provides a river channel on which we can visit them; takes the smoke from the air, and makes of the farmer's life a continual course of scientific and engineering study, interesting and of value to the nation?

RESULTS

Is that not worth while? Indeed we find it so. And we must cast about us for the manner of obtaining it.

We find that method in every department of government. The nation is concerned because the rivers are interstate. The states are concerned because the work lies within their borders. The cities are concerned because they need the power, the channel and the security from floods. The country people are concerned for the same reason and because they need to retain their soil. So we must work out our plans for every river, and having formed a plan we must make it law. This means that we must form fellowships, or societies to undertake the work, or we must force our states into agreements which Congress will sanction by which it must be carried out. These two plans, or that of a national Department of Public Works carrying out the work on each river under sanction of the state, on bond issues, and charging the improvement to pay for the bonds. And when it is done turning it over to the people,

THE CONSERVATION OF WATER

dividing the income among the cities and the counties, and allowing it to pay for the development of public benefits everywhere. That is the sane and reasonable plan. In the end it requires fundamental changes in our attitude toward our government and its laws. We must all come as some have come now to the belief that the spirit of the law requires them to be administered for public rather than private gain. The effort of our lawmakers and law enforcers must be not to alienate what the people own for private development, but to retain it and develop it under public control so that we may all together get the benefit of it. We have passed the day when we need fear to take up national development as a nation and state development as a state. We must come to that problem fairly in Conservation, and all the rights and privileges which lie in running water must be thrown open and held open for all, as state and nation.

The end even then will be slow in coming, but it will be steady. Every year some new dam

RESULTS

will hold back some new reservoir and take another foot off the crest of a flood. Every low water season will see deeper water in the channel. Every year will see less and less soil crumbling into the rivers, more acres of protective forests well cared for, more public docks, more public electric power, more income reverting to the nation and the state to carry on the work.

We will not see it done, nor our children. But our grandchildren will come to it by birth and education and sweep it on rapidly to complete perfection. And the trip up the river which I have described, which you who read this may never make, your grandson will make while still a young man, and he will make it with that new pride and delight in his own land which he cannot have until he has taken care of it, saved and protected it and made it a beautiful and a lovely place.

INDEX

- Adirondack mountains, 121
- Alabama, 32, 48, 121, 148, 231, 236
- Alleghany mountains, 31
- Alleghany river, 81
- Alps, the, 223, 226
- Alton, Ill., 264
- Apache Indians, 196, 199
- Arizona, 180, 196, 197
- Arkansas, 48, 147, 151, 153, 157, 158
- Arkansas river, 123
- Atchafalaya river, 154
- Augusta, Ga., 111, 117

- Babylon, 181
- Bad Lands, the, 206
- Baton Rouge, 152
- Bavaria, 133
- "Belle of Memphis," 157
- Bellows Falls, Vt., 45
- Big Sandy river, 36, 251
- Black river, 154
- Bohemia, 47, 48, 73
- Boston, Mass., 87, 88
- Bremen, 262
- Bridgeport, Ill., 84, 85
- Broward, Gov. Napoleon B., 172
- "Bubbly Creek," 84
- Bureau of Soils, 240, 241

- Cairo, Ill., 9, 10, 39, 81, 122, 254
- California, 23, 123, 127, 148, 170, 174, 180, 216
- Canalization, 249-253
- Carey act, 182, 190-194, 216
- Carson City, Nev., 211
- Carson river, 211
- Cass lake, 61
- Catskill mountains, 81, 89, 121
- Central Colorado Power Co., 126
- Chanoine Wicket dam, 251
- Charleston, S. C., 166
- Chicago, its water supply, 81, 83-87, 93; mentioned, 112, 116, 117, 123, 150, 263
- Chicago canal, 86, 87, 263
- Chicago, Milwaukee and St. Paul R. R., 129
- Chicago river, 84
- Chicopee river, 44
- Chile, 131
- Chippewa river, 76
- Cincinnati, 37
- Clark's Fork, 123, 207
- Cliff Dwellers, the, 197, 199
- Colorado, 123, 126, 210, 211
- Colorado river, 196, 221
- Columbia river, 63, 64, 123,

INDEX

- 124, 139, 179, 183, 201, 209, 265
 Columbus, Ky., 152
 Congress, authority over rivers, 17, 26, 27, 112, 113, 116, 150
 Connecticut, 115
 Connecticut river, described 44-46; mentioned, 106, 115, 116
 Conservation of the soil, 220-244
 Conservation of water, its aim, 8; its elements, 13; its importance, 27; the first step in, 53; its relation to swamp drainage, 145, 169-172, 174-175; its relation to irrigation, 176-179, 181-182, 202, 216-219; its relation to conservation of the soil, 220-244; its relation to navigation, 245-266; its results, 267-281
 Coosa river, 107, 265
 Croton river, 89
 Cumberland river, 37
 Dams. See *Canalisation, Reservoirs, Roosevelt Dam.*
 Danube river, 248
 Darnell-Watson feud, 154
 Death Valley, 211
 Deerfield river, 44
 Des Chutes river, 30, 124, 209
 Des Moines rapids, 122
 Des Moines river, 32
 Dismal Swamp, 150
 Doe river, 100, 101, 102, 231
 Dover, N. H., 107
 Drainage. See *Swamp drainage*
 Duluth, 140, 141
 Durance, the, 4, 224
 Egypt, 181
 Electric power. See *Water-power*
 Erosion of soil, 220-238
 Euphrates river, 181
 Everglades, the, 149, 172, 173
 Exhaustion of soil, 241
 "Fall Line" of Appalachians, 121, 137
 Fellowship of the Neisse, 49-52, 60, 115
 Fish propagation, 13
 Flambeau river, 76
 Flathead lake, 63, 64, 207
 Flathead river, 63, 123, 207
 Flood prevention, 14, 38-52
 Floods, 28-47
 Florida, swamp drainage in, 172-175; mentioned, 147, 150, 151
 Forests, necessary for conservation of water, 13, 65-78
 "Forty-mile Desert," 211
 Fox river, 76
 France, 4, 23, 24, 68, 112, 223, 224, 226
 French Broad river, 231
 Gallatin range, 32
 Garonne, the, 226, 227
 Gascogne, 226, 227
 Genossenschaft of Bohemia. See *Fellowship of the Neisse*
 Georgia, 121, 231, 236, 240
 Germany, 73, 118, 223

INDEX

- Gibbons vs. Ogden, 16
 Gila river, 196
 Girardeau, Cape, 152, 153
 Glacier Park, 207
 Glenwood, Colo., 126
 Gore Cañon, 126
 Grand Rapids, Wis., 74
 Great Falls, Mont., 22
 Great Lakes, the, 53, 60, 245
 Great Northern R. R., 129
 Great Plains, the, 32
 "Green coal," 4
 Grenoble, 4
 Griffith, E. M., 73
 Gunnison-Uncompaghre project, the, 210, 211-215

 Hamburg, Germany, 262
 Hartford, Conn., 45, 46
 Helena, Ark., 152, 153, 154
 Hetch-Hetchy valley, 92
 Holland, 149, 167, 169, 170
 Hollybush, Ark., 41
 Holston river, 232
 Holyoke, Mass., 45, 46, 106
 Hood river, 180
 Hudson river, 89, 265
 Hymelia, La., 41

 Idaho, 123, 124, 142, 179, 183, 192, 216
 Illinois, 14, 82, 116, 117, 147, 155, 189, 238, 242, 263
 Illinois and Michigan canal, 84, 85
 Illinois river, 32, 85, 86, 139, 253
 India, 181
 Indiana, 32

 International Falls, 141
 Irrigation, 11, 13, 15, 19, 21, 23, 25, 176-219
 Itasca, Lake, 32

 James Bayou gang, 157
 James river, 33
 Jersey marshes, 150
 John Day falls, 124

 Kanawha river, 36
 Kentucky, 48, 157, 228, 229-231, 235
 Kentucky river, 36
 Keokuk, Iowa, 108, 113, 122
 Klamath lake, 174, 180, 215
 Kouchiching, Minn., 140

 L'Anguille river, 154
 La Fourche, Bayou, 154
 Lakes-to-the-Gulf channel, 263
 Landes, the, 226, 227
 Law as applied to water, 14-27
 Leech lake, 61
 Levees, on the Mississippi, 10, 39-41, 150, 158, 159-160, 167, 257; on the St. Francis, 163, 164, 167
 Lewiston, Me., 107
 Licking river, 36
 Lignite coal, 203, 204
 Little Missouri river, 33
 Little River district, 161
 Loire river, 38
 Los Angeles, 90, 91
 Louisa, Ky., 251
 Louisiana, 48, 144, 147, 148, 149, 151, 154, 167-172
 Lowell, Mass., 106

INDEX

- Maine**, 147
Manchac, Bayou, 154
Manchester, N. H., 107
Massachusetts, 88, 115
McDonald, Lake, 207
Memphis, Tenn., 150, 152, 153, 159
Menominee river, 76
Merrimac river, 106
Metropolitan Water Commission (Mass.), 88
Michigan, 147
Michigan, Lake, 83, 85
Milk river, 203
Miller's river, 44
Milling, 21
Mining, 21
Minneapolis, 61, 111, 137, 141
Minnesota, 60, 140, 147, 148, 150, 151, 166
Minnesota river, 32
Mississippi, 147
Mississippi river, its lesson, 9; described, 31-33, 247; its levees, 39-41, 159-160; basins at head of, 60-62; erosion on, 232-235; mentioned, 18, 28, 37, 38, 59, 64, 86, 94, 103, 108, 113, 117, 122, 139, 141, 145, 149, 151, 152, 153, 154, 155, 156, 157, 158, 161, 162, 165, 166, 169, 220, 222, 257-258, 261, 262, 264, 265, 266
Missouri, 29, 48, 148, 151, 152, 153, 157, 158, 161
Missouri river, described, 32-34, 247; irrigation projects along, 202-206; erosion on, 232; mentioned, 22, 38, 123, 126, 160, 258
Montana, 22, 123, 126, 179, 189, 202, 206, 216
Morgan, Col. George, 155
Mormons, the, 182
Municipal water supply, 79-96
Muscle Shoals, Tenn., 107, 122, 139
Navigation, 13, 15, 245-266
Neisse river, 47-52
Nevada, 112, 180, 210
New England, 107, 121, 149, 150, 174, 238
New Hampshire, 44, 115
New Madrid, Mo., 155, 156
New Mexico, 180
New Orleans, 18, 39, 81, 139, 155, 167, 263
New York (city), 80, 87, 89, 98
New York (state), 31, 121, 148, 238, 265
New York Central R. R., 129
New York, New Haven and Hartford R. R., 129
Newell, Frederick H., 195
Nile, the, 181
Nitrate manufacture, 130-136, 173
Nolichucky river, 231
North Carolina, 32, 147, 231
North Dakota, 179, 206, 232
Norway, 112, 133
Ohio, 32, 228
Ohio river, described, 34-38, 247; mentioned, 30, 31, 56, 81, 122, 139, 160, 228, 248.

INDEX

- 249, 250, 251, 252, 253, 258, 259, 260, 261
- Okechobee, Lake, 173
- Okefenokee, 150
- "Open channel" development, 247-249
- Oregon, 23, 25, 26, 113, 114, 123, 124, 174, 180, 183, 209, 215, 216
- Owen river, 90.
- Ozark Mountains, 152, 155
- Pacific Gas and Electric Co., 126
- Palouse wheat country, the, 179
- Panama Canal, 261, 262
- Peedee river, 265
- Pend d'Oreille river, 63, 123, 207
- Pennsylvania, 31, 34
- Peshtigo river, 76
- Phoenix, Arizona, 197, 200, 201
- Pima Indians, 200
- Pittsburg, 34, 35, 36, 81, 122, 249
- Platte river, 33
- Point Pleasant, Mo., 233
- Pokegama lake, 61
- Pondage, 105
- Port Arthur, Canada, 141
- Portland, Ore., 124
- Prairie du Rocher, Ill., 28
- Prickley Pear valley, 22
- Priest's Rapids, 124
- "Prior Right," 19, 21, 22
- Protective Forests, 227
- Prussia, 47, 48
- Pumping, 201-205, 207, 208, 209
- Pyrenees, the, 226
- Rainfall, 5, 31, 34, 55, 56, 124, 189, 190
- Rainy Lake river, 139, 140
- Rainy river, 27, 125
- Reclamation act, 182, 194-195
- Reclamation Service, 174, 195, 202, 208, 210, 211, 213, 216
- Red river, 154, 169
- Reelfoot, 156, 157
- Reichenberg, 49, 53
- Reno, Nev., 211
- Reservoirs, the making of, 57-60; at head of the Mississippi, 60-62; necessary for irrigation, 63-64; their effect in Wisconsin, 77, 78; at Roosevelt Dam, 200; at headwaters of Columbia river, 208-209; in Truckee-Carson project, 211; their use for navigation, 259
- Revetment, 234, 255
- Rhone, the, 224, 226, 227
- Riparian rights, 15, 19
- Rock Island rapids, 122
- Rocky Mountains, 32
- Romans, the, 80
- Rome, Ga., 239
- Roosevelt, Arizona, 197, 200
- Roosevelt, Theodore, 26, 113, 264
- Roosevelt Dam, 196-201
- Sacaton Indian reservation, 200